THE PHYSICAL SCIENCES

OF

THE HINDUS

BY



DR. BRAJENDRA NATH SEAL, M.A., PH.D.,

KING GEORGE V PROFESSOR OF PHILOSOPHY IN THE UNIVERSITY OF CALCUTTA.

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SUDHINDRA NATHA VASU, AT THE PANINI OFFICE,
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CHAPTER I.

HINDU IDEAS ABOUT PLANTS AND PLANT-LIFE.

SECTION 1.

CLASSIFICATION OF PLANTS.

Charaka :—Plants according to Charaka are divisible into (1) *Vanaspatis*, trees bearing fruit without flowers ; (2) *Vânaspatyas*, trees bearing flowers as well as fruits ; (3) *Auṣadhis*, herbs that wither after fructification; and (4) *Virudhs*, other herbs with spreading stems.

Chakrapâṇi :—Chakrapâṇi notes in his commentary on Charaka : the *Virudhs* comprise two classes (1) *Latás*, creepers : (2) *Gulmas*, herbs with succulent (or cactaceous) stems and shrubs. The *auṣadhis* are sub-divided into (1) annuals or perennials, bearing fruit, and (2) plants that wither away after maturing and without fructification, *e.g.*, grasses like the *Durvâ* (Cynodon dactylon).

Susruta and Dalvana :—Susruta's division is identical with Charaka's. Dalvana, the commentator, gives some details. The *plakṣa* (Ficus infectoria) and the *Udumvara* (Ficus glomerata) are given as instances of trees bearing fruits without flowers (*vanaspatis*). It appears that plants with naked and incomplete flowers (Achlamydeous plants) were considered as flowerless, as also trees whose flowers like those of the fig are placed on the internal walls of a common receptacle. Of the *Brikṣas* flower and fruit-bearing trees, the mango tree, the *Jambu* tree (Eugenia jambolana) &c., are given as examples. The *virudhs* are of two classes—(1) creepers with stems spreading on the ground (प्रतानवत्य:) and (2) herbs, with succulent (or cactaceous) stems (गुल्मिन्य: or स्तम्बिन्य: वर्संल्लतासन्ततिविशिष्टा:). *Auṣadhis* are those that wither away after fructification, *e.g.*, wheat, barley &c., (फलपाकनिष्ठागोधूमादय:) Some divide *auṣadhis* into two classes (1) those that wither after bearing fruit, *e.g.*, paddy, linseed, pulses, &c., and (2) plants that wither after maturity, and bear neither flowers nor fruits, *e.g.*, the mushroom, &c.

Praśastapâda :—Praśastapâda, the Vaiśeṣika Doctor, classifies plants as follows :—(1) *Triṇas*, grasses ; (2) *Auṣadhis*, herbs that wither after fructification ; (3) *Latâs*, spreading and creeping herbs ; (4) *Avatânas*, arboraceous plants and shrubs ; (5) *Brikṣas*, trees bearing flowers and fruits; and (6) *Vanaspatis*, trees bearing fruits without flowers.

Srîdhara :—Srîdhara in the *Kandalî* gives *ulapa* as an example of a grass, wheat as an example of *auṣadhi* (annual), the *ketakî* (Pandanus odoratissimus) and the *Vijapura* (Citrus medica) as examples of *avatânas* (Vitapas, arboraceous plants), the *Kovidâra* (Bauhinia) as an example of flower and fruit-bearing tree and the *audumvara* (Ficus glomerata) as an example of a *vanaspati* (flowerless fruit-bearing tree).

Udâyâna ;—Udayana in the *Kiranâvalî* notes the *kuṣmânda* (a species of Cucurbita) as an instance of a creeper (*latá*), and the palms तालादय: as modifications of the grasses *Triṇas*.

Amara, the lexicographer, in the *Vanauṣadhivarga* and the *Vaisyavarga* (enumeration of wild plants and of food-grains) gives some interesting particulars. (1) The trees (the flowering *Brikṣas* and the flowerless *vanaspatis*) are fruit-bearing, and possess woody stems काष्ठद्वार or trunks (प्रकाण्ड—प्रकाण्ड: स्कन्ध: स्यान्मूलात् शाखाविस्तर:). Next come (2) arboraceous plants and shrubs (क्षुप, ह्रस्वशाखाशिफ: क्षुप:) bearing flowers as well as fruits. (3) The *latás* are next noticed, flowering plants with herbaceous stems, some of them creeping on the ground (प्रतानिनी),

others succulent (गुल्मिनी), others twining or voluble (मूलाच्चाग्रं गता लता, वृक्षगामिनी लता—Amara. cf. Mukuta, तरुमूलात् प्रभृति वृक्षाग्रपर्य्यन्तं गता गुडूच्यादि लतापि अवरोहः—others call this शिफा). Cf. Susruta—लताः प्रतानवत्यः गुल्मिन्यश्च.

(4) Next come the *auṣadhis* (in the narrower sense), herbaceous plants, bearing fruit with or without flowers and dying or withering away after fructification. Some instances of *kandasáka* (tubers, rhizomes, corms) are noticed, *e.g.*, the *palandu* (the onion पलाण्डुस्तु सुकन्दकः), the *lasuna* (garlic, महाकन्द), &c. But the graminaceao enumerated in the *Vaisyavarga* are the chief instances of the *auṣadhis*—plants that die after fructification. These are cultivated *auṣadhis*, but their affinities with the next class, the grasses (*Trinas*), are also noted (*e.g.* धान्य व्रीहि स्तम्बकरी। स्तम्बो गुच्छस्तृणादीनाम्। तृणधान्यानि नीवाराः। नाडीनालं च काण्डोऽस्य). Last are enumerated (5) the *Trinas*, grasses, of which the characteristic is the formation of *gulmas*, (culms of grasses with annular knots from which leaves spring—स्तम्बो गुल्मे तृणादीनामकाण्डद्रुमगुच्छयोः). It is worthy of note that, in the enumeration of the grasses, the bamboo is considered as a sort of giant grass (तृणध्वज, grass flag, तृणेषु ध्वज इव). The reeds (नलादयः) are also placed among the grasses (नलादयस्तृणं गर्मुच्छ्यामाकप्रमुखमपि। प्रमुखशब्दात् नीवारादयः). (6) Finally, the Palmaceae (including the cocoanut, date, areca, and other palms) are classed as Tree grasses, probably because, like the grasses, they are endogens characterised by spikes and parallel veins. तृणद्रुमाः (तृणराजाह्वयस्तालः नारकेलस्तु लाङ्गली etc. घण्टे च हिन्ताल सहितास्त्रयः खर्जूरः केतकी ताली खर्जूरी च तृणद्रुमाः—cf. also the *Rajanighantu*).

I may add that Amara places (7) parasitical plants among the *latas*, (वन्दा वृक्षादनी। वृक्षरुहा। जीवन्तिकेत्यपि). They climb trees and feed upon them. These are to be distinguished from climbing plants, like the *guduchi* (Tinospora cordifolia), which have separate roots of their own. They are also to be distinguished from the adventitious roots descending from the branches of trees, like the Ficus religiosa, which are usually termed *avarohas* (अवरोहाः).

The name *sipha* is ordinarily applied to the rootlets and suckers by which the tendrils of various creepers are attached to the soil. (शाखा शिफा अवरोहः स्यात्। वटादेः शाखायाः अवलम्बिनी शिफा। मूलाच्चाग्रं गता लता। मूलादूर्ध्वं गता लता स्यात् Amara with Bhanuji Diksita's commentary. But the Mukuta notes:—तरुमूलात् प्रभृति वृक्षाग्रपर्य्यन्तगता गुडूच्यादि लताऽपि अवरोहः। The *guduchi* is also called वत्सादनी, छिन्नरुहा).

The Hindu Materia Medica mentions *Âkasavalli*, lit. sky-creeper, a name which seems to have been originally intended for some orchids; also *plava* (lit. floating), weeds that float in stagnant ponds, and Saivala, mosses and lichens. (*e.g.*, दूर्वाकसेरुत्यश्शैवाल जलेन क्वथित पीत मूत्रमेहहर—*Chakrapaṇi-Samgraha*, also *Bhava-Prakasa*). These are not classified, but like the mushrooms must come under the *Pakavistha auṣadhis*, Ausadhis that die after maturing, without bringing forth flowers or fruits.

Section 2.

ELEMENTARY IDEAS OF PLANT PHYSIOLOGY.

Characteristics of plant life.

The *Nyaya-vindu-tika* of Dharmottara, the Buddhist Scholiast, notices the phenomenon of sleep (contraction of leaves in the night) in certain plants (स्वापः रात्रौ पत्रसङ्कोचः)

Udayana notices in plants the phenomena of life, death, sleep, waking disease, drugging, transmission of specific characters by means of ova, movement towards what is favourable and away from what is unfavourable (वृक्षादयः प्रतिनियतभोक्त्रधिष्ठिताः जीवनमरणस्वप्नजागरणरोगभेषजप्रयोगबीजसजातीयानुबन्धानुकूलोपगमप्रतिकूलापगमादिभ्यः प्रसिद्धशरीरवत्—Udayana, पृथिवी निरूपणम्). I may add that metaphors drawn from the heliotropic movements of the Suryyamukhi flower are among the stock-in-trade of Sanskrit poetry and belles-lettres.

The Jaina writer, *Guṇaratna*, in his commentary on the *Shaddarśana-Samuchchaya* (circa 1350 A.D.), enumerates the following characteristics of the plant-life: (1) stages of infancy, youth and age, (2) regular growth, (3) various kinds of movements or action, connected with sleep, waking, expansion and contraction in response to touch, also movement towards a support or prop, (4) withering on wound or laceration of organs, (5) assimilation of food according to the nature of the soil, (6) growth or decay by assimilation of suitable or unsuitable food as prescribed in the science of the diseases of plants and their treatment (वृक्षायुर्वेद), (7) disease, (8) recovery from diseases or wounds by the application of drugs, (9) dryness or the opposite, due to the sap which answers to the chyle (रस) in animals, and (10) special food favourable to impregnation. (विशिष्टदौहृदादिमत्त्वं विशिष्टस्त्रीशरीरवत् यथा स्त्रीशरीरस्य तथाविधदौहृदपूरणात् पुत्रादिप्रसवनं तथा वनस्पतिशरीरस्यापि तत्पूरणात् पुष्पफलादिप्रसवनं) Even the Vanaspatis (flowerless, but fruit-bearing trees) may be made to flower (Cf. Varahamihira's recipes for the treatment of plants for similar purposes).

(Cf. Guṇaratna, *Tarkarahasyadipikâ*, *Jainamâlâ*, śloka 49).

Sankara Misra in the *Upaksâra* notes as an additional characteristic the growth of organs (or tissues) by natural recuperation after wound or laceration भग्नक्षतसंरोहणे च Upaskâra, Chap. IV, Ahnika 2, Sutra 5 S. B. H. Vol. vi).

Guṇaratna gives a list of plants that exhibit the phenomena of sleep and waking:— शमीप्रपुन्नाटसिद्धेसरकासुन्दकबब्बूलागस्त्यामलकीकतिप्रभृतीनां स्वापविबोधतः — *ibid*). He also notices the sensitiveness to touch of plants like the *Mimosa pudica* लज्जावती लता, which show a manifest reaction in the form of contraction लज्जालुप्रभृतीनांहस्तादिसंस्पर्शात् यत्र सङ्कोचादिका परिस्फुटा क्रिया उपलभ्यते (*ibid*).

Sexuality.

Very vague ideas were entertained as to the sexual characters of plants. The pollen is called *Rajas*, *puṣpa*, *prasuna*,—names which are also applied to the female menstruum—and Amara expressly states that for females and flowers these elements (and the terms signifying them are the same स्त्रीणां सुमनसां पुष्पं प्रसूनं समम् Amara, *Vanauṣadhivarga*). Charaka (Dridhavala), indeed, distinguishes between the male and the female *vatsa* (or *kutaja*), considering the variety that bears white flowers and large fruits as male (बृहत्फलश्वेतपुष्पः पुमान् Holarrhena antidysenterica), and that which bears red or yellow flowers and small fruits as female श्यामारुणानुपुष्पी स्त्री—असित कुटज Wrightia tinctoria; Charaka, *Kalpasthâna*, (Chap. 5); but this is hopelessly wrong. Even these vague ideas were afterwards completely lost; and the *Râjanighantu* tells us of a grotesque division of plants into male, female and hermaphrodite, based on the slender or stout, the soft or hard, the long or short, the simple or mixed character of the stems and flowers! (*Râjanighantu*, अनूपादि प्रथमो वर्गः स्त्रीपुंनपुंसकत्वेन त्रैविध्यं स्थावरेष्वपि etc.)

Consciousness.

The Hindu Scriptures teach that plants have a sort of dormant or latent consciousness, and are capable of pleasure and pain (अन्तःसंज्ञा भवन्त्येते सुखदुःखसमन्विताः). Chakrapâni notes in the *Bhânumati* that the consciouness of plants is a sort of stupefied (darkened or comatose) consciouness (वृक्षास्तु चेतनावन्तोऽपि तमश्छन्नज्ञानतया शास्त्रोपदेशविषया एव)।

Udâyana also notes that plants have a dormant unmanifested consciousness which is extremely dull अतिमन्दान्तःसंज्ञतया, etc.)

The following ślokas from the Mahâbhârata may fitly conclude this section:

घन्यानामपि वृक्षाणामाकाशोऽस्ति न संशयः।
तेषां पुष्पफलव्यक्तिर्नित्यं समुपपद्यते॥
ऊष्मतो म्लायते पर्णं त्वक् फलं पुष्पमेव च।
म्लायते शीर्यते चापि स्पर्शस्तेनात्र विद्यते॥

वाय्वग्न्यशनि-निर्घोषैः फलं पुष्पं विशीर्य्यते ।
श्रोत्रेण गृह्यते शब्दस्तस्माच्छृण्वन्ति पादपाः ॥
वल्ली वेष्टयते वृक्षं सर्व्वतश्चैव गच्छति ।
नह्यदृष्टश्च मार्गोऽस्ति तस्मात् पश्यन्ति पादपाः ॥
पुण्या पुण्यैस्तथा गन्धैर्धूपैश्च विविधैरपि ।
अरोगाः पुष्पिताः सन्ति तस्माज्जिघ्रन्ति पादपाः ॥
पादैः सलिल-पानाश्च व्याधीनाञ्चापि दर्शनात् ।
व्याधिप्रतिक्रियत्वाच्च विद्यते रसनं द्रुमे ॥
वक्त्रेणोत्पलनालेन यथोर्द्ध्वं जलमाददेत् ।
तथा पवनसंयुक्तः पादैः पिबति पादपः ॥
सुखदुःखयोश्च ग्रहणात् छिन्नस्य च विरोहणात् ।
जीवं पश्यामि वृक्षाणामचैतन्यं न विद्यते ॥ शान्तिपर्व्व, महाभारत ।

CHAPTER II.

HINDU CLASSIFICATION OF ANIMALS.

SECTION 1.

CLASSIFICATION OF ANIMALS.

Charaka.

Charaka mentions four primary divisions :—

(1) *Jaráyuja*, born from the uterus, or rather, placentalia, viviparous (no a-placenta mammals were known), *e.g.*, man, the quadrupeds, etc.

(2) *Andaja*, born of an ovum (egg), comprising fishes, reptiles and birds.

(3) *Svedaja* (or *Uṣmaja*) born of moisture and heat, spontaneously or a-sexually generated, *e.g.*, worms, mosquitoes, etc.

(4) *Udvijja*, born of vegetable organism (भूतानां चतुर्विधा योनिर्भवति जरायण्डस्वेदोद्भिदः — Sárirasthána, Chapter III) चतुर्णां योनिः अपरिसंख्येयभेदा भवन्ति भूतानामाकृतिविशेषा परिसंख्येयत्वात् *Ibid.*

Praśastapáda.

Praśastapàda begins with two great divisions: (1) Ayonija, animals that are a-sexually generated, of small dimensions (क्षुद्रजन्तु). (2) Yonija, sexually generated, *i.e.*, from the union of a sperm and a germ element. The latter are subdivided into (*a*) *Jaráyuja*, lit., placentalia, viviparous (no a-placental mammals were known), and (*b*) *Andaja*, oviparous. Man, the quadrupeds, domesticated and wild, etc., are given as examples of viviparous animals; and birds, *Sarisripas* (reptiles, etc.) of oviparous animals.

Udáyana.

Udáyana in the *Kiranávali* notes that *Jaráyu* means the placenta (गर्भवेष्टनचर्म्मपुटकं जरायुः cf. Sridhara in the *Kandali*, जरायुरिति गर्भाशयस्य अभिधानं तेन वेष्टितं जायते इति जरायुजम्). Udayana adds that the term '*Sarisripa*,' includes insects and fishes as well as reptiles, these being all oviparous (सरीसृपाः परितः प्रसर्पणशीलाः सर्पकीटमत्स्यादयः — पृथिवीनिरूपणम्).

Patanjali.

The a-sexually generated animals, as we have seen, are also called *Kṣudrajantus* (lit. small animals). Patanjali in the *Mahábháṣya* gives several alternative definitions

(or descriptions) of this class of animals :—They are defined (1) as animals without bones अनस्थिका: क्षुद्रजन्तव: or (2) as animals that do not possess any blood of their own येषां स्वं शोणितं नास्ति ते क्षुद्रजन्तव: or (3) as numbering more than a thousand in a palmful, *i.e.*, minute in size, or (4) as not easily crushed, or (5) as comprehending all animals up to the ichneumon (in the animal series) अथवा नकुलपर्य्यन्ता क्षुद्रजन्तव:—Mahábhâṣya 2-4-1).

Susruta.

Susruta mentions four great divisions :—(1) *Sansvedaja*, born of moisture and heat. This division is mentioned first, as Dalvana notes, because moisture and heat are essential factors in the generation of all forms of animal life, including the classes that follow. (2) *Jarâyuja*, viviparous or placental, (3) *Andaja*, oviparous, and (4) *Udvijja*, bursting forth (from the ground or perhaps from some previous unmanifest shape, *e.g.*, frogs, coccidæ etc.) The second, third and fourth classes are mentioned in the order of their importance. Subsequently the order of enumeration is changed :—(1) *Jarâyuja*, (2) *Andaja*, (3) *Svedaja*, (4) *Udvijja*. One reading gives the order (1) Svedaja, (2) Andaja, (3) Udvijja and (4) Jarâyuja. Some commentators point out that the order in the text (whatever that may be) is intended to indicate the order of creation by Brahmâ.

Susruta mentions man, *Vyâla* (carnivorous quadrupeds) and *Pasu* (herbivorous quadrupeds) as examples of the viviparous ; birds, snakes and *Sarisripas* as examples of the oviparous ; *Krimis*, *Kîtas* and *Pipîlikâs* (worms, insects, ants, etc.) as examples of the moisture-born ; and frogs and the coccidæ (the coccinella) as examples of the animals that 'burst forth' (eruptive or metamorphic ?)

Dalvana.

Dalvana notes that the divisions are really cross-divisions (योनिसंकर) and intended to be such, as the natural divisions of Jiva and species are not all exclusively oviparous or exclusively viviparous. For example, among birds (पक्षिण: winged animals), bats and *Valâkâs* are viviparous (वलाका जतुकादय: जरायुजा:). Indeed *Valâkâs* are some of them oviparous and some viviparous (पक्षिषु वलाका जरायुजा अण्डजाश्च). Among snakes, the *Ahipatákás*, a species of non-venomous colubrines snakes, are viviparous (ovo-viviparous ?). Among the moisture-born, there are some kinds of ants (पिपीलिका:) which also lay eggs or burst forth (from the ground or perhaps from some previous unmanifest shape)—(स्वंस्वेदजेष्वपि काश्चित् पिपीलिका अण्डजा उद्भिजाश्च)

The oviparous animals are divided by Susruta into birds, snakes, *sarisripas*, etc. Dalvana notes that the *Sarisripas* include fishes, and *Makaras* (sea-fish with fierce teeth—हिंस्रदंष्ट्रका:), and the 'et cetera' comprehends tortoises and crocodiles (सरीसृपा: शीघ्रगामिन: कृष्णसर्पादयो मीनमकरादयो वा प्रभृति ग्रहणेन कूर्म्मनक्रादीनां ग्रहणम्) ! The 'moisture-born' are due to the moisture and heat either of the earth, or of organisms (स्वंस्वेदजा: भुव: शरीरस्य च संस्वेदात् ऊष्मण: जाता:). Of these, the *Krimis* (worms) arise from the moisture of the fæces in the bowels (क्रमय: कोष्ठपुरीषादिवाष्पसंभवा:—Dalvana), from putrefying dead bodies (शव Susruta ;—cf. शरीरे कियद् वेलानन्तरं समुत्पन्नानां कृम्यादीनां कथं चैतन्यम्—Guṇaratna, *Tarka-rahasya-dîpikâ*, (*Jainamatam*) ; from decomposing curd or milk (*e.g.*, वर्षासु च स्वेदादिना अनतिदवीयसैव कालेन दध्याद्यवयवा एव चलन्त: पूतनादिकृमिरूपा उपलभ्यन्ते —Jayanta, *Nyâyamanjarî*, *Ahnika* 7, भूतचैतन्यपक्ष).

The second class, *Kîtas*, noticed among the moisture-born, include the scorpions, the six-spotted venomous insect *ṣadvindu*, &c., (कीटावृश्चिकषड्विन्दु प्रभृतय: Dalvana). Of these the scorpions arise from cow-dung, excreta of snakes, rotten wood (कथं गोमयाद् वृश्चिक: जायते —Pâtanjali, Mahâbhâṣya 1-4-3) Cf. also Susruta, *Kalpasthâna*, Chapter 7.

The third class, *Pipilikás*, ants and the like insects, Dalvana notes, are born of moisture and heat, as well as of eggs, and sometimes burst forth from the ground (भुवमुद्भिद्य जाता उद्विज्जा - Dalvana). The gnats and mosquitoes (दंशमशकादय:) are also usually placed among the moisture-born. An *anda* (egg) is described as oval, of the form of a *pesi* (muscle ?)—(अण्डं पेश्याकारवत्तुलं—Dalvana. Cf. Sridhara, Kundali, अण्डं बिम्बं तेन वेष्टितं जायते तत् अण्डजं, पृथिवीनिरूपणं)

Chhândogya and Sankara.

It may be noted that the *Chhândogya Upanisada* classifies animals on the basis of their *vija* (ovum or seed), as threefold :—(1) *Andaja*, born of eggs ; (2) *Jivaja*, viviparous ; and (3) *Udvijja*. Sankara explains that the udvijja animals arise from vegetable organisms (उद्भित् स्थावरं ततो जातम् उद्विज्जम्) which is also Charaka's view, as we have seen. But unlike Charaka, Sankara holds that the *svedaja* animals must be included partly under the oviparous, and partly under the *udvijja* (vegetable-born) class (अण्डजोद्विज्जयोरेव यथासम्भवमन्तर्भाव:) (Chhândogya, Prapâthaka 6, Part 3).

Evidently the idea is that, though vegetable organisms may pass off into animal, there cannot be generation without *vija* (seed or ovum), and inorganic matter without *vija* (seed or ovum) cannot give rise to animal life. Pâtanjali, in the *Mahâbhâsya* (circa 150 B.C.) mentions the opposed view, which holds that not only animal organisms but also vegetable organisms, *e.g.*, grasses, grow from inorganic matter. The Durvâ grass, for example, can grow from deposits of the hair of goats and cows, just as scorpions are seen to develop out of cow-dung. Pâtanjali notes the orthodox Sânkhya-Vedânta explanation that these are not cases of growth (or transformation) but merely of coming out (अपक्रामन्ति) कथं गोमयाद् वृश्चिको जायते गोलोमाविलोमेभ्य: दूर्वा जायन्ते इति अपक्रामन्ति ता वस्तुभ्य: —Mahâbhâsya, 1-4-3.

The Dietary Animals in Charaka and Susruta.

In noticing different kinds of meat for dietary purposes, Charaka gives a classification of animals (mammals and birds) which has only a practical (therapeutic) significance.

The dietic value of the flesh of any animal was conceived to depend mainly on its habitat and mode of life. Dietary animals (mammals and birds) were accordingly divided into eight classes (अष्टविधा योनिरस्तेषाम्)

(1) *Prasaha*, carnivorous as well as non-carnivorous (Chakrapâṇi), comprehending land-quadrupeds and birds that fall on their food with force,

(2) *Anupa*, animals that live in marshy or water-logged lands or graze on river banks,

(3) *Bhusaya* or *Vilesaya*, animals that live in underground holes,

(4) *Vârisaya*, aquatic animals, both fresh-water and oceanic,

(5) *Jalachara*, amphibious animals,

(6) *Jângala*, animals that live in dry and elevated (hilly) jungle lands, mostly species of deer,

(7) *Viṣkira*, birds that scatter their food in picking up, and

(8) *Pratuda*, birds that pierce or torment their food (worms and fruits) with the beak.

In the chapter on articles of diet, Susruta gives a practical classification of (vertebrate) animals for dietary purposes. Animals that find a place in this dietary are first divided into two classes :—(I) *Anupa*, animals that live in marshy or water-logged land (or in water) ; (II) *Jângala*, animals that live in dry (hilly) jungle land. The Jângalas are divided into five classes, and the Anupas into eight. The thirteen classes are based on real and natural distinctions of food and habitat ; they are for dietary purposes arranged

under six conventional (or artificial classes) (त्रयोदश भेदा षड्सु एव अन्तर्भूत । सन्येयम् । निर्द्दिष्टादेव षड्संख्यायां लब्धायां षड्ग्रहणम् तेन षड्वर्गा इति नियमार्थम्—Dalvana, Sutrasthâna, Chapter 27). These thirteen classes of dietary animals may be enumerated as follows :—

I. *Jángala* animals—*Janghála, Viṣkira, Pratuda, Guhásaya, Prasaha, Parṇamriga, Vilesaya* and *Grámya*, and

II. *Anupa* animals—*Kulechara, Plava, Kośastha, Pádina* and *Matsya*.

Of these, the *matsyas* (fishes) are divided into two groups, freshwater (lit. river-water) and sea-water fishes. Among the sea-fishes, the Timi and the Timingala (cod-fish or whales ? तिमिमहत्तमो मत्स्य: तिमिङ्गलस्ततोऽपि महत्तम:—Dalvana) find a place, as also the *makara*, (shark—हिंस्रदंष्ट्राक:—Dalvana).

The *kosastha* (living in shells-mollusca) are distinguished from the *matsyas* (fishes). In this class are enumerated *sankhas* (conchifera), *sankhana* (smaller conchifera), *sukti* (pearl mussels), *sambuka* (Helix) with spinal shell (आवर्त्तकोश:—Dalvána.) *valluka* (a species of Helix, according to some (सन्ने सम्बुक भेदभापु: Dalvana), etc. Dalvana adds *rodika, jalasukti*, and various species of Helix (वोडिकजलशुक्तिशम्बूकभेदा बहुविधा गृह्यन्ते)

The *pádinas*, aquatic animals having pedal (or long dorsal) appendages, comprise the *kurmas* (oval or oblong-shaped tortoises, turtles), the *kumbhiras* (crocodiles, emydosauria, reptilia), the *karkatas* (white and black crabs, crustacea), the *sisumara* (a species of the Delphinidæ cetacea) muscular, with a sharp protruding snout, breathing with the blow-hole *out of the water*, probably a dolphin, as the long dorsal fin was taken for a sort of pedal appendage (दंड्राकारोद्दर्ध्व वक्त्र: वहिर्निश्वासं मुञ्चति सोऽपि द्विविध: वर्त्तुलदीर्घभेदेन —Dalvana). The *pádinas* do not represent any natural division.

Of the other *Anupa* animals (aquatic or amphibious animals), the *plavas* (lit., floating on the water) represent a class of birds (the Natatores and the Grallatores) exemplified by geese, ducks, cranes, &c.

The *Kulecharas* are herbivorous quadrupeds that frequent the banks of rivers and ponds, and comprise the elephant, the rhinoceros, the *Gávaya* (*Bos gavæus*), the buffalo, various species of deer, &c.

Of the land-animals (*Jángala*), three of the sub-divisions represent birds, and five, mammals. The Land-Birds are (1) the *Prasaha* birds, birds of prey proper (Raptores), comprising the vultures, kites, hawks, owls, &c. (Charaka's *Prasaha* is a much wider class) (2) the *Vishkiras*, birds that scatter their food in picking up, and (3) the *Pratudas*, birds that pierce or torment their food (fruits or worms) with the beak. The last two classes comprehend between them the *Passeres* (proper and so-called), the *Scansores*, the *Rasores* and the *columbæ*.

The remaining five classes of *Jángala* animals are mammals, with the exception of several species of *Vilesayas*, which are reptiles. The *Parṇamrigas* (arboreal animals) comprise the apes, sloths, squirrels, as also some of the reptiles and carnivora. Among the *Parṇamrigas*, the *Putighasa* is a kind of tree-cat giving out a pungent odour ; the *madgumuṣika* and the *Brikṣasáyika*, are arboreal rodents ; and the *Avakusha*, is a species of cow-tailed monkey (*vide* Dalvana). The *Janghálas* are wild animals, herbivorous quadrupeds that are strong-legged and quick-footed, comprising various species of deer and antelopes.

The *Grámyas* (lit., living in or about villages, domesticated quadrupeds) comprise the horse, the mule, the ass, the camel, the goat, the sheep, &c. They are non-carnivorous, being distinguished from the carnivorous quadrupeds (क्रव्याद्—Susruta, मांसाद Charaka). Some are *Ekasapha* (animals whose hoofs are not cloven) (ग्राम्यशब्देन च एकशफशब्देन च ग्राम्या:—शफ: खुर:—Dalvana).

The *Guhâsayas* are carnivorous quadrupeds (क्रव्यादाः) living in natural caves or hollows. They comprise the lion, the tiger, the wolf, the hyena, the bear, the panther, the cat, the jackal, the *mrigevaru*, &c. The *vrika* (wolf) is defined as a dog-like animal, small-sized (in comparison with the lion and the tiger). By the cat, here, wild cats are meant. The *mrigevaru* is described as a jackal-like animal that kills deer.

Finally come the *Vilesayas*, animals that live in holes or burrow, comprising various species of Rodents and Insectivora, and several species of Reptiles.

Snakes in Nâgârjuna.

The Snakes (ophidae) are especially noticed by Susruta. (Nâgârjuna in the chapters relating to Toxicology. *Kalpasthana*, Chapter 4). Five different genera or families are noticed, of which one is non-venomous, and four venomous, including one hybrid and three pure or unmixed families. Of the last, (1) the *Darvikaras* (कृष्णसर्प महाकृष्ण, पद्म, महापद्म, गडुमपाली.— Tripudians, Naia Bungarus, Colubridae) are hooded, swift in their movements, diurnal in their habits, and bear on their hoods or their bodies the marks of chariot wheels, ploughs, umbrellas, rhombs or cross-bands, goads, &c. (2) The *mandali* (Vipera and Trimeresums, Viperidae ?) are thick (पृथवः), slow-moving, nocturnal in their habits, and bear circles or rings on the body (व्याद्दर्गमण्डल). Charaka adds that they are without hoods. (3) *Ragimats* also are without hoods and nocturnal, and bear series of dots or marks, and are often of variegated colours on the upper parts and sides (Colubridae, Bungarus Callophis, Dryophis, &c., ?). Twenty-six varieties are named of the first, two of the second, and ten of the third.

Of the *Nirvisas*, non-venomous snakes, twelve varieties are mentioned, including Boidae अजगर and the columbrine Dendrophis. (वृक्षेशय) Of the *Vaikaranjas* (hybrid) snakes, there are ten varieties, of which three are produced by the union of certain venomous species, and seven are secondary derivative forms.

The *Danikaras* are most deadly when young, the *Mandalis* when middle-aged, the *Ragimats*, when aged. Their poisons act differently, and an elaborate description is given of the action of the venom of each of the three venomous families.

Snakes in the Purâṇas.

The *Bhaviṣya Purâṇa* gives the following additional information. The *Nâgas* (Naiae, Colubridae, Snakes) copulate in the month of *Jyaistha* or Âṣâḍha (May or June), gestate during the rainy months that follow, and bring forth about two hundred and forty eggs in the month of *Kartika* (November). Most of these are devoured by the parents, but those that are left break forth from the shell in about two months (or one month, according to the *Agnipurâṇa*).

Eggs of a golden hue like that of the (red) flowers of the *Calotropis gigantea* (सुवर्णार्कवर्णनिभ) produce male young ones, those somewhat paler and of an elongated ovoid shape (अर्कादृक्सुवर्णाभान् दीर्घराजीवसन्निभान् bring forth female snakes, and those of the hue of the *Siriṣa* blossom hermaphrodite ones. By the seventh day the young snakes turn dark: in a fortnight (or twenty days, according to another account) the teeth come out. The poison is formed in the fangs (दंष्ट्रासु) in three weeks, and becomes deadly in the twenty fifth night. In six months, *Nâgas* shed the skin (कञ्चुक).

In moving on the ground, the folds of the skin on the under-surface alternately expand and contract, appearing to put out and draw in fine filament-like legs, about 240 in number. The joints on the skin (scabs or scutes सन्धयः) are two hundred and forty in number (perhaps the sub-caudals were not counted).

Snakes are killed by men, mungooses, peacocks, *Chakoras* (a kind of partridge), scorpions, boars, cats, and the hoofs of oxen. Escaping death from these enemies, a

Nâga may live for a hundred and twenty years. The term of life of the non-venomous snake is shorter, about seventy-five years. (*Bhavişya Purâņa* पञ्चमीकल्प).

The *Agnipurâņa* gives the total number of teeth (of a Nâga) as thirty-two; of which four (two on either side) are venomous; *viz.*, *Kâlarâtri* and *Yamadutikâ*, which appear to be the names of the fangs, and *Karâli* and *Makari* which seem to stand for two hard (maxillary) teeth accompanying the two fangs (cf. also Charaka—Dridhavala, *Chikitsâ-sthâna*, XXIII, विषचि कित्सितम्).

Umâsvati's Classification of Animals.

A more thorough classification of animals is found in the ancient Jaina work, the *Tattwârthâdhigama* of Umâsvati, which the Jaina chronological lists enable us to assign with great probability to the fourth or fifth decennium after Christ (circa 40 A.D). Umâsvati's classification is a good instance of classification by series, the number of senses possessed by the animal being taken to determine its place in the series. Perhaps only senses actively determining the life-habits were counted.

I. First come animals with two senses, *viz.*, touch (as evidenced by contractility of tissue) and taste (as involved in the selection and rejection of food). This division comprises—

(*a*) *Apâdika* (Vermes without lateral appendages, Scolecids).

(*b*) *Nupuraka* (Ring-like, with pendants, vermes with unsegmented lateral appendages, Annelids).

(*c*) *Gandupâda* (Knotty-legged, Arthropoda, including Crustacea, Myriapoda, &c).

(*d*) Some forms of Mollusca, *e.g.*, *Sankha* (Conchifera, Lamellia branchiata), *Suktikâ* (Pearl-mussel, Lamellla branchiata), and *Sambuka* (Helix).

(*e*) *Jalukâ*, Leeches (Annelids).

II. Next come the animals with three senses, namely, smell in addition to the primordial senses of touch and taste involved in the contraction of tissues and the appropriation of food. Here also well-developed and active senses alone were perhaps intended. Rudimentary or dormant senses were not reckoned. This division comprises—

(*a*) *Pipîlikâ* (Ants, Formicidæ, Hymenoptera).

(*b*) *Rohinikâ*, red ants (Formicidæ, Hymenoptera).

(*c*) *Upachikâ*, *Kunthu*, *Tuburaka*, bugs and fleas (Hemiptera, Hemimetabola).

(*d*) *Trapusavija* and *Karpâsasthika*, cucumber and cotton weasels and lice (Aptera, Ametabola).

(*e*) *Satapadi* and *Utpataka*, Spring-tails (Aptera, Ametabola).

(*f*) *Triņapatra*, Plant lice.

(*g*) *Kâstha-hâraka*, Termites, white ants (Neuroptera, Hemi-metabola).

III.—Then come the animals with four well-developed and active senses, *i.e.*, sight, smell, taste and touch.

This division comprises—

(*a*) *Bhramara*, *Varata*, and *Sâranga*—Bees, Wasps and Hornets (Hymenoptera, Holometabola).

(*b*) Makşikâ, Puttikâ, Dansa and Masaka—Flies, Gnats, Gadflies and Mosquitoes (Diptera, Holometabola).

(*c*) Vrischika and Nandyavarta—Scorpions and Spiders (Arachnida, Arthropoda).

(*d*) Kita—Butterflies and Moths (Lepidoptera, Holometabola), and

(*e*) Patanga—Grasshoppers and Locusts (Orthoptera, Hemimetabola.)

IV.—Finally come the animals (man and the Tiryyak-yonis) with five well-developed and active senses. Omitting man, this division comprises—

(a) Matsya, fishes,
(b) Uraga,
(c) Bhujanga,
(d) Pakṣi, birds, and
(e) Chatuṣpada, quadrupeds.

Uraga and Bhujanga in popular use mean reptiles ; but here evidently Bhujanga is taken to mean oviparous limbed animals (limbed reptiles and batrachians) and not creatures whose movements are crooked or in the form of a bent bow; and Uraga stands for apodal reptiles including snakes (ophidæ).

It will be seen that the first three divisions fall under the Invertebrata, and the fourth is identical with the Vertebrata.

This last division (the Vertebrata) is sub-divided on a different basis, *viz.*, the mode of reproduction. The sub-divisions are three :—

A.—*Andaja*, oviparous (Pisces, Reptilia and Batrachia), *e.g.*, *Sarpa* (Snakes, Ophidia, Reptilia), *Godha* (Varanidæ, Lizards, Reptilia), *Krikalāsa* (Chameleons, Reptilia), *Griha-golika* (Common Lizards—Lacertilia), Matsya (Pisces) *Kurma* (Tortoises—Chelonia, Reptilia), *Nakra* (Crocodiles, Reptilia), *Sisumāra* (Dolphin or Porpoise, Cetacea) and Birds proper with feather wings—the *Lomapakṣa pakṣis*.

Porpoises are erroneously put here, being really viviparous like other cetacea. Frogs are not mentioned in this list. The omission is strange. Perhaps (as in Susruta) frogs were believed to be *Udbijja* (eruptive or metamorphic) and not *Andaja* (oviparous). But Susruta mentions the frogs after the quadrupedal and centipedal Reptilia (*Kanaua*, *Godheraka*, *Galagolika* and *Satapadi*).

B.—*Jarāyuja*, mammals born with placenta, including all mammals other than the *Potaja*. (Here *Jarāyuja* is used in a restricted sense) :—(1) Man, (2) Cow, (3) Buffalo, (4) Goat and Sheep, (5) Horse, (6) Ass, (7) Camel, (8) Deer, (9) Yak (*Chamara*), (10) Hog, (11) Bos Gaveus (Gāveya)—Ungulata, (12) Lion, (13) Tiger, (14) Bear, (15) Panther, (16) Dog, (17) Jackal, (18) Cat (Carnivora), etc.

The apes, though not expressly mentioned, are also to be included.

C.—*Potaja*, a class of placental mammals comprising the Deciduata with the exception of Man, the Apes and the Carnivora :—*e.g.* *Sallaka* (Porcupine, Rodentia), *Hasti* (Elephant, Proboscidea), *Svavit* and *Lipaka* (Hedgehogs and other creatures that lap up, Insectivora), *Sasa* and *Sayika* (Hare, Rabbits and Squirrel, Rodentia), *Nakula* (Ichneumon, which though carnivorous is supposed to come under the Deciduata), *Muṣik* (Mice, Rodentia) and the *Charma pakṣa Pakṣis*, so-called birds with leathern wings (Bats, Chiroptera), *e. g.*, *Valguli* (Flying Fox), *Pakṣivirāla* (Flying Cat, Micro-Chiroptera) and *Jalukā* (apparently meaning blood-sucking Bats or Vampires, though these are scarcely found in the old world).

The *Potaja* class thus comprises the following Deciduata :—Proboscidea, Rodentia, Insectivora and Chiroptera.

The term *Potaja* is intended to signify that these animals are born without the placenta which is thrown off as an after-birth, whereas such of the *Jarāyujas* as are not *Potajas* are born with the placenta attached to the embryo. But it is not easy to explain why man, the Apes and the Carnivora should not also be reckoned among the *Potajas*.

कृम्यादीनां पिपीलिकादीनां भ्रमरादीनां मनुष्यादीनां च यथासंख्यमेकैकवृद्धानि इन्द्रियाणि

भवन्ति। यथाक्रमम्। तद् यथा कृम्यादीनां अपादिक-नूपुरक-गण्डूपद-शङ्ख-शुक्तिक-शम्बूक-जलूका-प्रभृतीनां स्पर्शनरसनेन्द्रिये भवतः। पिपीलिका रोहिणिका-उपचिका-कुन्थुतुवुरक-त्रपुसबीज-कर्पासास्थिका-शतपद्युत्पतक-तृणपत्र-काष्ठहारक-प्रभृतीनां त्रीणि स्पर्शनरसनघ्राणानि। भ्रमर-वरट-सारङ्ग-मक्षिकापुत्तिका-दंश-मशक-वृश्चिक-नन्द्यावर्त्त-कीट-पतङ्गादीनां चत्वारि स्पर्शनरसनघ्राण चक्षूंषि। शेषानां च तिर्य्यग्-योनिजानां मत्स्योरगभुजङ्गपक्षि-चतुष्पदानां सर्वेषां च नारकमनुष्यदेवानां पञ्चेन्द्रियाणि। (Umâsvati, Tattvarthâdhigaṇa, Chap. II, Sutra 24).

जरायुजानां मनुष्य-गो-महिषाजाविकाश्व-खरोष्ट्र-मृग-चमर-वराह-गवय-सिंह-व्याघ्रर्क्ष-द्वीपि-श्व-शृगाल-मार्जारादीनाम्। अण्डजानां सर्प-गोधा-कृकलास-गृहगोलिका-मत्स्य-कूर्म्म-नक्र-शिशुमारादीनाम्। पक्षिणां च लोमपक्षाणां-हंस-चाष-शुक-गृध्र-श्येन-पारावत-काक-मयूर-मद्गु-बक-बलाकादीनाम्। पोतजानां शल्लक-हस्ति-श्वाविल्लायक-शश-शायिका-नकुल-मूषिकादीनाम् चर्मपक्षिणां च पक्षाणां जलूका-वल्गुलि-भारण्ड-पक्षिविरालादीनां गर्भोजन्म। (Umâsvati, *ibid*, Chap. II, Sutra 34).

SECTION 2.

RE-CAPITULATION.

The ancient Hindu classification of animals, as gathered from the authorities mentioned above, may be briefly summarised thus :—

A.—*Kṣudrajantus*, boneless and without (red) blood. Invertebrata, divided into

(a) *Ayonija*, a-sexually generated, *e.g.*, the *Svedaja*, born of moisture and heat, and the *Udvijja* (vegetable-born, *e.g.*, the coccinella) and

(b) *Yonija*, sexually generated, *e.g.*, the *Andaja*, oviparous.

But some are both a-sexually and sexually generated, being both *Svedajas* and *Andajas*, or *Udvijjas* and *Andajas*.

The *Kṣudrajantus* (Invertebrata) comprise—

(I) the *Krimis* vermes : (*a*) *Apâdikas* without lateral appendages (cf. Scolecids), (*b*) *Nupurakas*, Annelids (a section), (*c*) *Gandupadas*, Arthropoda (a section).

(II) the *Jalukâs*, Leeches, of which twelve species are described, six venomous, and six innocuous (cf. Susruta's careful description, *Sutrasthâna*, Chap. 13),

(III) *Kosasthas*, shelled animals, some forms of mollusca, *e.g.*, the *Saukhas* (Conchifera), the *Suktikas* (Pearl-mussels), the *Sambukas* (spiral-shelled, Helix), the Vodikas, etc.,

(IV) then the Insects typified by the Ants, comprising

- (a) *Pipîlikâ*, *Rohiṇikâ* (Ants, Hymenoptera).
- (b) *Upachikâ*, *Kunthu*, *Tuburaka* (bugs and flies, Hemiptera).
- (c) Cucumber and cotton lice (Aptera).
- (d) *Satapadi*, *Utpataka* (Spring-tails, Aptera).
- (e) *Triṇapatra*, grass or plant lice (Aptera).
- (f) *Termites* (Neuroptera).

(V) Insects typified by the Hexopoda, comprising—

- (a) *Bhramara*, *Varata*, *Sâranga*, Bees, wasps and hornets,
- (b) *Makṣikâ*, *Puttikâ*, *Dansa*, *Masaka*, Flies, gnats, gadflies, and mosquitoes,
- (c) *Vrischika* and *Nandyâvarta*, Scorpions and spiders (Arachnida, Arthropoda),
- (d) *Kîta*, Butterflies and moths, and
- (e) *Patanga*, Grasshoppers and locusts.

Susruta-Nâgârjuna names six varieties of ants, six varieties of flies, five of mosquitoes, (including one marine and one mountain kind), eight varieties of *Satapadis* (centipedes), thirty varieties of scorpions and sixteen of spiders (*Lutâs*). Of the *Kitas*, the glow-worm and the *Tailakita* (lit., oil-worm) are said to be luminous (phosphorescent, (cf. *Râjanighantu* खद्योततैलकीटी).

B.—The *Tiryyakyoni* animals, sexually generated animals other than such of the ovipara as are included under the *Ksudrajantu*, in other words, sexually generated animals possessing bones and blood—corresponding to the vertebrata—comprise the following classes :—

I. *Andaja*, oviparous :—

(*a*) The *Matsyas*, fishes, divided into river-water fishes and sea-fishes.
Susruta names eleven species of the latter. The '*Timi*' (cod-fish, whale) is reckoned as a sea-fish. The *Makara* (shark) is also mentioned, but the *Kurmas*, *Kumbhiras* and *Sisumâras* (tortoises, crocodiles, and dolphins) are excluded from the class, as also the so-called shell-fish, being placed among the *Pâdinas* and the *Kosasthas* respectively.

(*b*) The *Uragas*, apodal reptiles :—including the Sarpas (snakes, ophidia). Five classes of snakes are mentioned, one non-venomous, three venomous, and one hybrid. Eighty varieties of snakes are named, but the classification is based on superficial characters, *e.g.*, markings on the scales, etc., and do not touch any anatomical peculiarities. The pathological observations regarding the distinct action of the poisons of different orders seem to be good.

(*c*) *Bhujangas*, oviparous animals with lateral, pedal appendages, both Reptiles and Batrachians. Many of these are quadrupedal and five-clawed. चतुष्पादाः कीटाः पञ्चनखाः (Dalvana.)

Illustrations.

1. *Godha*, *Grihagolika* and *Krikalasa* (Varantas lizards, common lizards and chameleons). Susruta names four varieties of the *Kanava*, a species of chameleon-like lizards—(cf. Lâdyâyana quoted by Dalvana, *Kalpasthâna*, Chapter 8). also six varieties of *Galagolika* (a species of lizards), and five varieties of *Godheraka*, Varanus-like lizards, but smaller in size.

2. *Kurmas* and *Nakras*, tortoises and Crocodiles (Chelonia and Emydosauria, Reptilia). Some species of the former are oval, others elongated (वर्त्तुलदीर्घाद्भिर्भेदाः)

3. *Sisumâras*, the Delphinidæ (Odontocete cetacea).

Susruta mentions the frogs (*Udvijja*, eruptive or metamorphic ?) after the quadrupedal and centipedal Reptilia (*Kanava*, *Godheraka*, *Galagolika* and *Satapadi*). Eight species of frogs are named. The frogs are explained by the mythologist to have arisen from dirty water in the rainy season. ..... प्रावृट्काले ततः (*i.e.* महेश्वरशुक्रात्) मण्डोदके जाता . cf. Dalvana, *Kalpasthâna*, Chapter 8.

Susruta's *Pâdinas* (aquatic animals having pedal or long dorsal appendages) are a conventional class formed for practical dietary purposes, and include (2) and (3) and also the Karkatas, crabs, (crustacea). *Umâsvati's* Bhujanga class, being a natural sub-division of vertebrates, does not include crustacea which are rightly placed among the invertebrates.

(d) *Lomapakṣa pakṣi*, winged animals with feathery wings, Birds proper. These are oviparous, while the winged animals with leather wings (चर्म्मपक्षपक्षिणः) are placentalia of the Deciduata class (पोतजाः)

The Birds proper are divided into four classes :—

(1) *Plavas*, aquatic or amphibious birds, comprising the Natatores and the Grallatores. Various species are described.

(2) *Viṣkiras*, those that scatter their food in picking up.

(3) *Pratudas*, those that pierce or torment their food (fruits or grains).
The enumeration of the species under (2) and (3) shows that these two classes included the Passeres (veræ and so-called), the Scansores, the Rasores and the Columbæ.

(4) *Prasahas*, birds of prey proper (Raptores).

Dalvana's descriptions of deer and birds are precise, turning upon coloration, habits of life etc., *e.g.*, the descriptions of the Ruru, the Kârandava, and the Kanka, expressly quoted from some (unnamed) Hand-books :—

कूलचरमाह...रुरुः शरदि शृङ्गत्यागी । तल्लक्षणं उच्यते—

"विकटबहुविषाणः शम्बराकारदेहः सलिलतटचरित्वात् सम्बरेभ्यः विचित्रः । त्यजति शरदि शृङ्गं रौति"—इत्यसौ रुरुः स्यात् ।

कारण्डवःशुक्लहंसभेदोऽल्पः अन्ये करहरमाहुः । उक्तञ्च कारण्डवः "काकवक्त्रो दीर्घाङ्घ्रिः कृष्णवर्णभाक्" इति ।

प्रसहानाह...कङ्कः दीर्घचञ्चुर्महाप्राणः । उक्तं च "कङ्कःस्यात् कङ्क मलाख्यो बाणपत्रार्हपक्षकः । लोहपृष्ठो दीर्घपादः पक्षाधः पाण्डुवर्णभाक् ।" इति ।

The sources from which Dalvana derives detailed information about these varied forms of animal life are now unavailable, but these extracts abundantly testify to the minute nature study of the Hindus.

The Hindus had of course no idea of an anatomical classification of birds.

The ancient writer, Lâdyâyana, had a much better idea of zoological description in reference to the *Kitas* (insects and reptiles, *vide infra*).

II.—*Jarâyujas*, (viviparous, lit., placentalia) in the usual wider sense ; comprising—

(a) *Charmapakṣa pâkṣis*,—leather-winged animals, which are deciduata (*Potaja*) Charaka calls them *Mrigapakṣiṇa* (mammal birds) and distinguishes them from the birds-of-prey proper, in his enumeration of the *Prasahas* (*Sutrasthâna*, Chapter 27). The Bats mentioned are :—

(1) *Valguli*, (flying fox),

(2) The *Pakṣi Virâla*, (flying cat, micro-chiroptera),

(3) The *Bharanda*, (a species of micro-chiroptera, the horse-shoe bat ?)

(4) The *Jaluká*, (lit., aquatic or amphibious or more probably leech, bat, blood-sucking or vampire bat ?). These are placed among carnivorous animals.

(b) The *Vilesaya Jarâyujas*, mammals that live in holes or burrows, including various species of Rodents and Insectivora, which are named. Eighteen different varieties of mice are specified (Susruta, *Kalpasthâna*, Chapter 6).

(c) *Parṇamrigas*, arboreal mammals, comprising some Rodents (squirrels etc.), a wild cat, the sloths and the apes (वानर).

(*d*) Non-carnivorous Quadrupeds (अक्रव्याद:) :—

(1) *Janghâlas*, lit., strong-legged quadrupeds, frequenting hilly and jungly tracts, comprising various species of deer (non-carnivorous wild animals, अक्रव्याद्).

(2) *Kulechara* mammals, grazing on the banks of rivers, and frequenting marshy places, comprising the elephant, the rhinoceros, the gaveya (Bos gavæus) the buffalo, the hog and also several species of deer (which live in well watered lands). These are also non-carnivorous (अक्रव्याद्)

(3) *Grâmyas*, (lit., living in or near villages), non-carnivorous domesticated quadrupeds, some with undivided hoof, others with cloven hoof,—comprising the horse, the mule, the ass, the camel, the cow, the goat, the sheep, etc. These are all non-carnivorous. The dog and the cat are not mentioned in the list.

(*e*) Carnivorous quadrupeds, *Guhâsaya* (living in natural caves or hollows, carnivorous *Kravyâda*),—comprising the lion, the tiger, the wolf (of the dog-class), the hyena, the bear, the panther, the cat, the jackal, etc. The carnivora were, termed *Vyâlas* or *Kravyâdas*, and the herbi-vora *Pasus* (in a wider sense).

(*f*) Man.

The term *Jarâyuja*, in a wider sense came to mean 'viviparous' and included the above orders of animals. But the Jainas used the term *Jarâyuja* in a narrower sense to mean only those viviparous animals which come out at birth with the placenta (a-deciduata). The deciduata (including the Proboscidea, the Rodentia, the Insectivora, the Chiroptera, etc.) were termed, *Potaja*, lit., viviparous animals born without placenta. Man, the apes and the carnivora are, however, reckoned with the *Jarâyuja* (viviparous, born with placenta). Perhaps the after-birth was observed in these cases, whereas the *Potajas* (deciduata) may have been erroneously conceived to throw off no placenta.

Lâdyâyana appears to have made a special study of the classification of *kitas* (Insects and Reptiles) and is quoted by Dalvana as a great authority on the subject.

The various forms (रूप) of *kitas* are to be distinguished from one another by peculiarities in the following marks :—

(1) Dottings or markings, (2) wings, (3) pedal appendages, (4) mouth, with antennæ or nippers,—मुखसन्दंश, Dalvana, (5) claws, (6) sharp, pointed, hairs or filaments (7) stings in the tails, (8) hymenopterous character (संश्लिष्टै: पक्षरोमभि:) (9) humming or other noise, (10) size, (11) structure of the body, (12) sexual organs (this is how I interpret *linga* here), and (13) poison and its action on bodies.

Cf. कटुभिः बिन्दुलेखाभिः पक्षैः पादैः मुखैः नखैः
शूकैः कण्टकलांगलैः संश्लिष्टैः पक्षरोमभिः ।
स्वनैः प्रमाणैः संस्थानैः लिङ्गैश्चापि शरीरगैः
विषवीर्य्यैश्च कीटानां रूपज्ञानं विभाव्यते ॥

Quoted from Lâdyâyana by Dalvana, *Kalpasthâna*, chapter 8).

CHAPTER III

HINDU PHYSIOLOGY AND BIOLOGY.

SECTION 1.

METABOLISM.[1]

The food that we eat contains five classes of organic compounds. From their radicles or predominant elements, the substances are named Earth-compounds, *Ap*-compounds, *Tejas*-compounds, Vâyu-compounds and Âkása-compounds. The Earth-compounds supply the hard formed matter of the body, the Tejas-compounds give the animal heat (or the metabolic heat), the Vâyu-compounds are the sources of the motor-force in the organism, the Ap-compounds furnish the watery parts of the organic fluids, and the Âkása-compounds contribute to the finer etheric essence which is the vehicle of the conscious life.

Roughly speaking, the Earth-compounds answer to the nitrogen compounds in the food, the Tejas-compounds to the hydro-carbons (heat-producing), and the Vâyu-compounds to the carbo-hydrates (dynamic). The Ap-compounds are the watery parts of food and drink. The flesh, for example, is a tissue composed principally of the Earth-compounds, the fat of the Earth and Ap-compounds, the bones of earth, Vâyu and Tejas compounds. Different operations of the metabolic heat (perhaps different digestive fluids are also meant) are required to digest the different substances in the food.

The course of metabolism is described as follows: The entire alimentary canal is called the Mahâsrotas (the great channel).

The food goes down the gullet by the action of the bio-motor force, the *Prána-Váyu.*

In the stomach (आमाशय) the food becomes mixed up, first with a gelatinous mucus (फेनीभूतं कफं) which has a saccharine taste, and then gets acidulated by the further chemical action of a digestive juice (विदाहादम्लतां गत: —evidently the gastric juice is meant). Then the bio-motor force, the *Samána Váyu*, begins to act and drives down the chyme, by means of the *Grahaṇi Nádi* to the *Pittásaya* (duodenum, lit. bile-receptacle) and thence to the small intestines (the आमपक्वाशय). In these, the bile (or rather the digestive substance in the bile, as opposed to the colouring element) acts on the chyme and converts the latter into chyle (रस), which has at first a *katu* taste (pungency). This chyle contains in a decomposed and metamorphosed condition all the organic compounds, *viz.*, tissue-producing Earth-compounds, water-parts or Ap-compounds, heat-producing Tejas-compounds, force-producing Vâyu-compounds, and, lastly, finer etheric constituents which serve as the vehicle of consciousness. The essence of chyle (सूक्ष्मभाग) from the small intestines is driven by the bio-motor force, the *Prána Váyu*, along a Dhamani trunk (cf. the thoracic duct) first to the heart (which is a great receptacle of chyle), and thence to the liver (and the spleen); and in the liver, the colouring substance in the bile acts on the essence of chyle, especially on the Tejas-substance therein, and imparts to it a red pigment, transforming it into blood. But the grosser part of chyle (स्थूल भाग) proceeds along the Dhamanis, being driven by the bio-motor force, the *Vyána Váyu*, all over the body.

When the blood has been formed, the essence of chyle in the blood, acted on by Vâyu (bio-motor force) and Mâmsâgni (the flesh-forming metabolic heat), forms the flesh-tissue, the Earth-compound of the food substance especially contributing to this tissue. Of the flesh-tissue thus formed, the grosser part goes to feed or replenish the flesh-tissue

[1] Extract from my monograph in Dr. Ray's *Hindu Chemistry* Vol. II.

all over the body. The finer essence of flesh in the blood in the chyle, acted on again by Vâyu (bio-motor current) and the fat-forming metabolic heat (मेदोऽग्नि) in the menstruum of lymph (कफं समाश्रित्य), receives viscosity and whiteness, and produces the fatty tissue, the Earth-compounds and Ap-compounds of the food specially contributing to the product. This fat in the chyle (or blood), or rather the grosser part of it, replenishes the fatty tissue of the body, but the finer essence of fat *in* the flesh *in* the blood *in* the chyle, acted on by *Vâyu* (bio-motor current) and the marrow-forming metabolic heat, in the menstruum of lymph (श्लेष्मणावृत), becomes hard (crystalline), and forms bone, the Earth, Vâyu and Tejas compounds contributing principally to the product. The essence of the fat fills the hollow channels of the bones, and acted on again by bio-motor *Vâyu* and metabolic heat, becomes transformed into marrow. The marrow is similarly transformed into the semen, which is conveyed down by means of a pair of *Dhamanis* or ducts (द्वे शुक्रवहे), lodged in its receptacles (शुक्रधरा – वृषणौ) and discharged by means of another pair of ducts (द्वेयिसगाय). The semen or rather all the elements in their finer essence, give off *ojas* which returns to the heart, the receptacle of chyle and blood, and again floods the body, and sustains the tissues, thus completing the wheel or self-returning circle of metabolism (परिवर्तिरतु चक्रवत् cf. Charaka and Vâgbhata).

It is to be noted that, throughout, the fluid in the chyle or blood acts as the menstruum, though occasionally, the lymph, which is itself a derivative from the chyle, is added, as in the case of the fatty tissue and the bones; and that each preceding element or constituent of the body (धातु—शरीरारम्भक धातु) takes up the proper organic compounds from the food chyle to form the next element or tissue. Throughout also, the chemical changes are due to the metabolic heat which breaks up the compounds and recombines, but the operations and even the vehicles perhaps of this heat are different. For example, these heat-corpuscles in the biliary ducts produce the bile, but the bile-secretion is supposed to contain two distinct substances: (1) a digestive fluid in the duodenum (पित्ताशय) which acts on the chyme to produce the chyle (अन्नस्य पक्तृ पाचकाख्य' पित्तं); and (2) a colouring bile-substance in the liver which adds a red pigment to the chyle, and transforms it into blood (रञ्जकाख्य' पित्तं). Besides, there are three other biles, of which the aqueous humour in the eye is supposed to be one (आलोचक पित्तं), helping in the formation of visual images (रूपग्राहकं). This is the view of Dhanvantari and his school, but Âtreya holds there is no evidence that the bile really performs the first (digestive) function, for this can be accounted for by the animal heat arising from the working of the whole bodily machine.

There are three different hypotheses regarding the course of metabolism and the successive transformations of the chyle (क्षीरदधिन्याय- केदारीकुल्यान्याय—खलेकपोतन्यायेति त्रिधा धातु पोषणक्रमः — Chakrapâṇi, Bhânumati, Sutrasthâna, XIV, 10; also his commentary on Charaka, Sutrasthâna, XXVIII), but my account is based on the second hypothesis which has the preference of Chakrapâṇi (स्वरस:). It may be added as a curiosity that each element of the body (धातु) under the metabolic heat is supposed to give off a finer essence (सूक्ष्मभाग) which serves as the material of the next succeeding element, and a dross (मल) which forms some of the excreta in the body (including the nails, the hair &c.), besides retaining its own substance (the gross or main part) which is driven along by the Vâyus (biomotor or vital currents), or by the *srotas*, to its destination in the body.

Some idea of circulation appears to have been entertained, for the heart which receives, and then sends down, the chyle through the *Dhamanis* gets it back transformed into blood, and the *ojas* also proceeds from the heart and returns to it along with the chyle and the blood.

(Cf. Vâgbhata ताः हृत्स्थाः शिराः रसात्मकं ओजः अभिवहन्त्यः)। पञ्चभूतात्मके देहे आहारः पाञ्चभौतिकः। विपक्वः पञ्चधा सम्यग् गुणान् स्वानभिवर्द्धयेत्। Susruta, *Sutrasthâna*, Chap. 46, cf. also, वियत्पवनजाताभ्यां वृद्धिमाप्नोति मारुतः। आग्नेयमेव यद्द्रव्यं तेन पित्तमुदीर्यते। *Ibid*, Chap 41. भौमाप्याग्नेयवायव्याः पञ्चोष्माणः सनाभसाः। पञ्चाहारगुणान् स्वान् स्वान् पार्थिवादीन् पचन्त्यनु। यथास्वं ते च पुष्णन्ति पक्त्वा भूतगुणान् पृथक्। पार्थिवाः पार्थिवानेव शेषाः शेषांश्च देहगान्। अतिरिक्ता गुणा रक्ते वह्नौ मांसे तु पार्थिवाः। मेदस्यपां भुवश्चास्थि पृथिव्यनिलतेजसां। Charaka quoted by Dalvana. आदौ षड्रसमप्यन्नं मधुरीभूतमीरयेत्, फेणीभूतं कफं यातं विदाहादम्लतां गतः। वायुना समानाख्येन ग्रहणीमभिनीयते। षष्ठी पित्तधरा नाम या कला परिकीर्त्तिता। आमपक्वाशयान्तःस्था ग्रहणी साऽभिधीयते। अग्न्यधिष्ठानमन्नस्य ग्रहणाद् ग्रहणी मता। भुक्तमामाशये रुद्धा सा विपाच्य नयत्यधः। बलवत्यबला त्वन्नमाममेव विमुञ्चति।...अन्नस्य पक्तृ पित्तन्तु पाचकाख्यं पुरेरितम्। दोषधातुमलादीनामुष्मेत्यात्रेयशासनम्।......तेजोरसानां सर्वेषामम्बुजानां यदुच्यते, पित्तोष्मणा सरागेण रसो रक्तत्व मृच्छति। वाय्वग्नितेजसा युक्तं रक्तं मांसत्व मृच्छति। श्लेष्माणं च समाश्रित्य मांसं वाय्वग्निसंयुतम्, स्थिरतां प्राप्य शौक्ल्यं च मेदो देहेऽभिजायते। पृथिव्यग्न्यनिलादीनां सङ्घातः श्लेष्मणावृतः, खरत्वं प्रकरोत्यस्य जायतेऽस्थि ततो नृणाम्। करोति तत्र सौषिर्यमस्थ्नां मध्ये समीरणः। मेदसा तानि पूर्यन्ते स्नेहो मज्जा ततः स्मृतः। तस्मान्मज्ज्ञश्च यः स्नेहः शुक्रं संजायते ततः। Charaka-Dridhavala Saṃhitâ quoted by Aruṇa in his commentary on Vâgbhata.

यथा केदारनिपक्तं कुल्याजलं प्रत्यासन्नां केदारीमाप्लावयति। तथा रस एव प्रथमं रक्तं प्लावयति। तत्र रक्तस्थान सम्बन्धात् रक्तसादृश्यं रक्तव्यपेदशंच अनुभवति। रक्तं च रक्तसमानेन स्तोकेनांशेन अस्त्रं पोषयति। ततो रक्त माप्लाव्य मांसमाप्लावयति, एवमुत्तरोत्तरधातून् रसएव प्लावयति। (Chakradatta Bhânumati). This passage shows that the 'venous blood' was conceived to be chyle-essence mixed with blood, and that the circulation of the chyle, so far as it was held to contribute its quota to the constituent elements and tissues of the body, was really supposed to be identical with the circulation of the blood (ततो रक्तमाप्लाव्य मांसमाप्लावयति). This will be abundantly clear from the following account of the course of the chyle and the blood :

ततः सारभूतस्याहाररसस्य द्वौ भागौ भवतः। स्थूलः सूक्ष्मश्च...ततः सूक्ष्मोभागः प्राणवायुनाप्रेरितो धमनीमार्गेण शरीरारम्भकस्य रक्तस्य स्थानं यकृत्-प्लीहरूपं गत्वा तेन सह मिलितोभवति। ततः प्राक्तन रक्तधातौ एव तिष्ठति।...ततः सारभूतस्य आहाररसस्य द्वौ भागौ भवतः। स्थूलः सूक्ष्मश्च। स्थूलो भागो रञ्जकाख्येन पित्तेन रक्तीकृतः शरीरारम्भकं रक्तं पोषयन् व्यानवायुना प्रेरितोधमनीभिः सञ्चरन् सकलशरीरगतानि रुधिराणि पुष्णाति। ततः सूक्ष्मोभागः व्यानवायुनाप्रेरितो धमनीभिः शिराभिश्च शरीरारम्भकाणि मांसानि याति। *et seqq.*

This finer essence of chyle which nourishes the flesh is also carried in the blood, on the irrigation channel hypothesis (केदारी-कुल्यान्याय).

SECTION 2.

THE CIRCULATORY SYSTEM.

The standing puzzle of Hindu anatomy and physiology is the classification of the *Siras*, *Dhamanîs*, *Śrotas*, the channels, passages, and ducts in the body, including the arteries, veins, nerves, lymphatic vessels, etc. The difficulty was felt by the ancient observers themselves. Some were of opinion that the *Dhamanîs* and *Śrotas* are only modifications of the *Śiras*, and that the division is artificial. Susruta, however, contends that

they are distinct, because they can be traced to different roots and have different functions ; they are apt to be confounded, only because they are minute, juxtaposed, and similar in function. (Susruta, *Śârîrasthâna*, Chapter IX). Charaka also accepts the established division, but points out that the numbers as estimated are conjectural (अनिर्द्देश्यमत: परं तर्क्यं नेव *Śârîrasthâna*, Chapter VII). .

The *Śiras*, *Dhamanîs* and *Śrotas* form net-works (जालानि) of cords, fibres, passages, which in the fœtus take their rise from the umbilical cord, and proceed, upwards to the heart and head, downwards to the kidneys and rectum, and outwards to the trunk and limbs. These three classes comprise all the vehicles or conductors of the fluids, secretions and currents in the bodily system.

The *Śrotas* (*currents*). This is a peculiarity of Hindu physiology. The chyle, the blood, the Vâyu, the metabolic fluid (पित्त), the lymph, the fat, the marrow, in every part of the body, is supposed to be connected by means of subtle currents (*Śrotas*) with the same kind of fluid (or tissue) in every other part. Without supposing such special connections, many pathological phenomena cannot be explained.

The *Śiras* are divided into four groups : (1) the arteries for conducting the blood, (2) the lymphatics for conducting the lymph, (3) a class of bile ducts, and (4) a class of ducts for the *vâyus*, the currents which work the automatic and reflex machinery of the living organism. In each group, there are 10 trunk *Śiras*, which sub-divide into 175 cords, and further ramify minutely all over the body, even as a net-work of minute fibrils covers the leaf of a tree.

The functions of the different groups of *Śiras* are to conduct or transmit the (arterial) blood, the lymph, the bile, and the (vital) *vâyu* currents respectively to the different parts of the body. The *Śiras* are compared to the conduits of the flowing water in a pleasure-house (a garden), or the channels of irrigation that flood a field. The conduction (or transmission) of the fluids and currents is effected by an alternate dilation and contraction of the vessels, the systolic movement differing according to the nature of the fluid propelled :

(सप्त शिराशतानि भवन्ति याभिरिदं शरीरमाराम इव जलहारिणीभिः केदारइव च कुल्याभिरुपस्निह्यते अनुगृह्यते च आकुञ्चनप्रसारणादिभिर्विशेषैः। द्रुमपत्त्रसेवनीनामिव तासां प्रतानाः। तासां नाभिर्मूलं ततश्च प्रसरन्त्यूर्द्ध्वं अधस्तिर्य्यक् च। तासां मूलशिराश्चत्वारिंशत्। तासां वातवाहिन्यो दश पित्तवाहिन्यो दश कफवाहिन्यो दश दश रक्तवाहिन्यः *Susruta*, *Śârîrasthâna*, Chap. VII.)

The *Dhamanîs* in the fœtus take their rise from the umbilical cord, thus bringing nourishment from the mother. They are divided into three groups : (*a*) ten trunks or cords going up to the heart, and thence to the head, (*b*) ten going down to the intestines, kidneys and rectum, and (*c*) four branching obliquely or sidewise, and ramifying over the whole body. In a general way, it may be stated that the *Dhamanîs* comprise (1) the veins, (2) the nerves (including the sympathetic system), (3) the chyle-ducts (including the thoracic duct) as distinguished from the other lymphatics, which are classed as *Śiras*, (4) the ducts for urine, sweat, and other secretions, and (5) lastly, certain classes of bile-ducts and conductors of Vâyu currents, possibly those connected with the venous system and the chyle-ducts.

The first group of *Dhamanîs* :—Special features : Each of the ten ascending Dhamanîs, on reaching the heart, trifurcates, and proceeds to the head. Of these fibres, one pair is engaged in conducting each of the four sensory currents (those of sound, colour, taste and smell), *from the sense-organs, as Charaka and Susruta must have supposed, to the heart, which is for them the seat of consciousness* (हृदयं विशेषेण चेतनास्थानम्, Susruta,

Śárîrasthâna, Chapter IV, हृदयं चेतनाधिष्ठानमेकम् Charaka, *Śârîrasthâna*, Chapter VIII). Other Dhamanîs, also in pairs, are engaged in conducting automatic (or voluntary) motor currents, (*e.g.*, the currents concerned in respiration, yawning, sleeping and waking), or the secretions of the lachrymal and mammary glands.

The second group of *Dhamanîs* :—Special functions :

The descending *Dhamanis* go down to the intestines, kidneys, bladder and rectum, and their special function is to convey, in pairs as before, urine and other secretions and excreta. They also convey the chyle from the small intestines to the ascending as well as the ramifying *Dhamanîs*. In addition, some of them convey sweat to the ramifying *Dhamanîs*.

The third group : Special functions. The remaining four *Dhamanîs* ramify obliquely over the body into millions of fibres and fibrillæ, which terminate in the pores of the skin. From all parts of the periphery, they conduct the sensory currents of touch to the central organ of the heart (including the internal organic sensations). Being connected with the pores of the skin, they conduct sweat outwards, and the influences of baths, embrocations, and fomentations inwards.

Other *Dhamanîs* serving as chyle-ducts and (venous) blood-vessels :—Besides the special functions performed by the three groups, there is one characteristic function common to certain classes of *Dhamanis* which are found in all the three groups—*viz.*, the conduction of chyle and (venous) blood, *i.e.*, of blood in the state of chyle, before it gets its red pigment from the liver. It may also be added that the three principal elements of the body, *Vâyu* (vital current), *Pitta* (bile, or rather the fluid animal heat which produces metabolism, पाक, and flows to all the parts of the body by means of connective passages), and *Kapha* (lymph), make use of the *Dhamanîs* as well as the *Śiras* and *Śrotas*, *i.e.*, of all manner of conductors in the organism (cf. Charaka, वातपित्त श्लेष्मणां पुनः सर्वशरीरचराणां सर्वाणि स्रोतांसि अयनभूतानि *Vimânasthâna*, Chapter V).

The functions of the *Śiras* may, therefore, be stated as follows :—

(1) The conduction of blood from the liver and spleen, red blood (what may be called the arterial blood of this system of physiology) to the heart, head, trunk, limbs, etc.

(2) Common functions of all connective passages, *viz.*, the conduction of *Vâyu* (vital current), *Pitta* (metabolic fluid), and *Kapha* (lymph).

The different classes of *Dhamanîs* with their functions are :—

(1) The nerves : (*a*) eight sensory (central) nerves for the four special senses other than touch, (*b*) twelve motor nerves partly for voluntary and partly for automatic movements, and (c) the nerves of touch and organic sensation, including the sympathetic nerves.

(2) The chyle-ducts, conductors of (venous) blood,—conveying the chyle before it is transformed into blood in the liver (and the spleen).

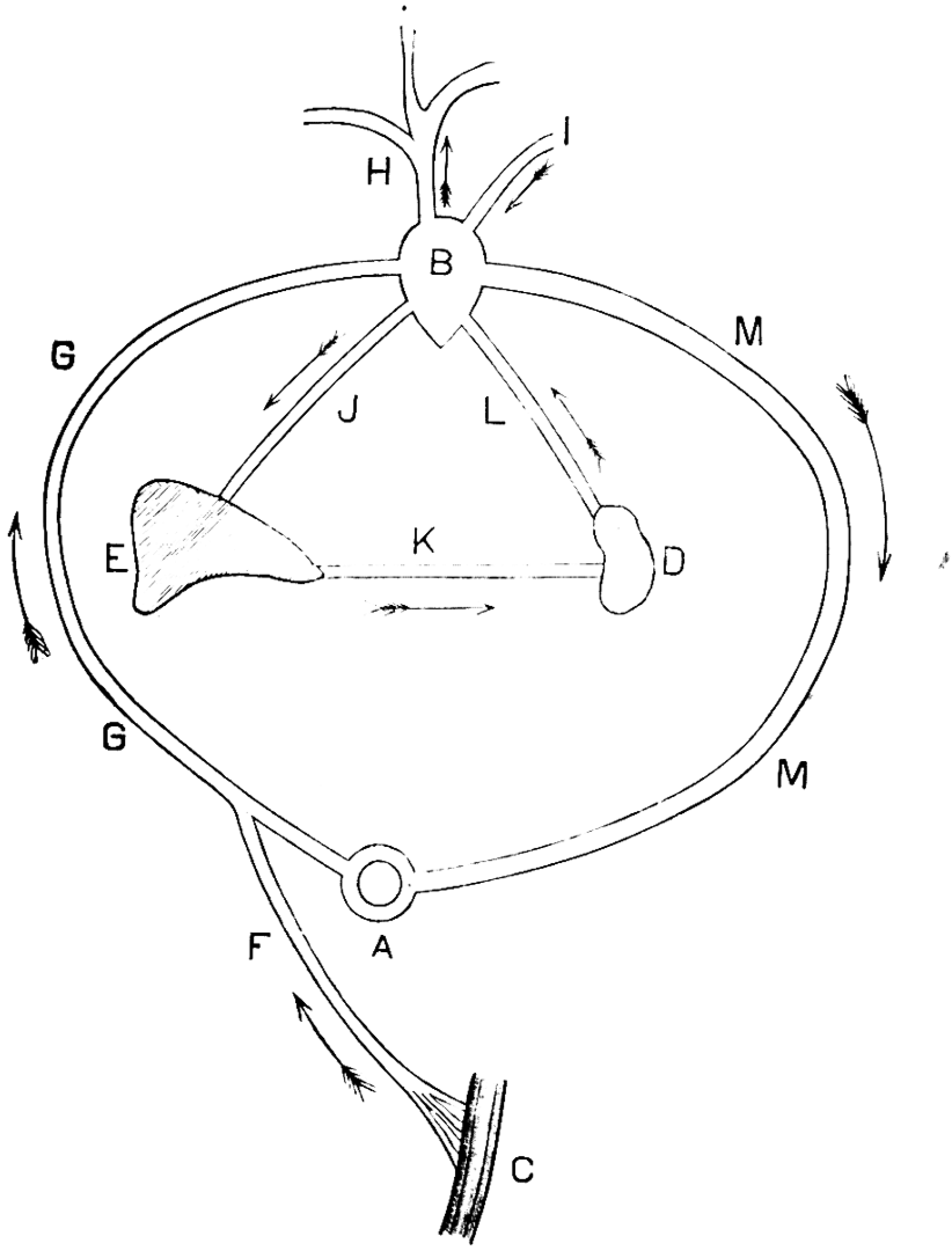
(3) The classes of *Dhamanîs*, which, in common with the *Śiras* and *Srotas*, conduct *Vâyu*, *Pitta* and *Kapha*,—the prime movers of the organic life.

ŚIRAS AND DHAMANÎS AS BLOOD-VESSELS.

THE CIRCULATORY SYSTEM.

The anatomical arrangement of the *Śiras* and *Dhamanîs* as conceived in this system of physiology is so fanciful and obscure (Charaka himself states that it is unascertainable and questionable) that it is with considerable diffidence that I attempt to reproduce in a chart the main features of the vascular and circulatory system. At the outset, I would premise that the mistake as to the relative position of the heart and the liver in man, which

lasted till the middle of the sixteenth century in Europe and took a Vesalius to correct, was impossible to the Hindu anatomists, who habitually practised dissection on human corpses.



Conjectural Restoration of the Diagram of the central circulation of the Śiras and Dhamanîs after Charaka and Susruta. The obliquely branching Dhamanis, and the ramifications of the Śiras are not shown.

(*a*) Navel,—the fœtal source of Śiras and Dhamanis,—may be taken as the starting point of the circulatory system.

(*b*) Heart (पुंडरीकेन सदृशं हृदयं स्यादधोमुखम् । जाग्रतस्तद्विकशति स्वपतश्च निमीलति । Susruta, Śârira-sthâna IV),—the receptacle of the chyle poured into it by the ascending Dhamanis;—source of the 'life currents' (प्राणवहानि स्रोतांसि), and seat of consciousness;—also supplies to the spleen and liver (venous) blood, or rather chyle mixed with blood, to be transformed

into red (arterial) blood. The heart is also supplied by Śiras with true blood. Cf. प्रसन्नाभ्यां कफासृग्भ्यां हृदयं पंकजाकृति। शुषिरं स्यादधोवक्त्रं (संगीतरत्नाकर)

(c) Small intestine (पित्ताशय) which receives the chyme from the stomach (आमाशय), and, with the help of the bile brought from the liver, turns the chyme into chyle.

(d) Spleen, a minor source of blood (or blood vascular gland); on the left below the heart.

(तस्याधोवामतः प्लीहा—Susruta, Chapter IV).

(e) Liver, the major source of blood; the chyle gets a red pigment in the liver (and spleen) and is converted into true (arterial) blood. The liver is to the right

(दक्षिणतो यकृत्—Susruta, Śârîrasthâna, Chapter IV).

(f) Dhamanî, conveying chyle from the small intestine to the great Dhamanî trunk (g) that ascends to the heart;—answers to the portal vein and thoracic duct (?)

(g) Dhamanî trunk, ascending from the navel to the heart; answers to the inferior Vena Cava.

(h) Dhamanî ascending from the heart to the head,—and trifurcating;—answers to the superior Vena Cava.

(i) Also, Dhamanî ascending from the heart, but brings back the (venous) blood to the heart (Pulm. Artery ?)

(j) Also, a Dhamanî, descending from the heart, and conveying the chyle and venous blood from the heart to the liver, where the blood takes a red pigment.

(k) Śira, connecting the liver with the spleen,—carrying the red blood from the liver to the spleen (Sp. vein).

(l) Śira, from the spleen to the heart, carrying the red blood to the heart.

(m) Śira, bringing red ("arterial") blood from the heart to the navel, the starting point, answering to the aorta.

N.B.—The Śiras ramify from the liver and the spleen, and supply the trunk, head and limbs, with red (arterial) blood. Four Dhamanî trunks also, for the trunk and limbs, issue from the navel. They ramify into veins and capillary vessels (as also nerve fibres and fibrils) and carry chyle and (venous) blood over the entire system.

It is clear that Charaka and Susruta had no idea of the part played by the lungs in the purification of the blood. The liver converts the 'venous' blood in this system into true ('arterial') blood, and along with the spleen serves as a basis of discrimination between a Śira and a Dhamanî, thus illustrating Susruta's statement that the distinction between these two kinds of blood vessels must be accepted as real, inasmuch as they have different sources and different functions.

तासान्तु नाभिप्रभवानां धमनीनामूद्ध्वंगा दश दश चाधोगामिन्यश्चतस्रस्तिर्यंगाः ऊद्ध्वंगास्तु हृदयमभिप्रपन्ना स्त्रिधा जायन्ते। अधोगमास्तु पित्ताशयमभिप्रतिपन्नास्तत्रस्थमेवान्तपानरसं विपक्वं औष्ण्याद् विरेचयन्त्यः अभिवहन्त्यः शरीरं तर्पयन्ति चोद्ध्वंगतानां तिर्यग्गतानां रसस्थानमभिपूरयन्ति (Susruta, Śârîrasthâna, Chapter IX). तत्र पांचभौतिकस्य आहारस्य सम्यक् परिणतस्य यस्तेजोभूतः सारः परमसूक्ष्मः स रस इच्छते। तस्य च हृदयं स्थानम्। स हृदयाच्चतुर्विंशतीः धमनीरनुप्रविश्य ऊद्ध्वंगा दश दश चाधोगामिन्यश्चतस्रस्तिर्यंगाः कृत्स्नं शरीरं अहरहस्तर्पयन्त। तस्य शरीरमनुधावतोऽनुमानाद् गतिरुपलक्षयितव्या। स खल्वाप्योरसः यकृत्प्लीहानौ प्राप्य रागमुपैति। (*Ibid*, Chapter IV). रंजितास्तेजसास्त्वापः शरीरस्थेन देहिनां रक्तमित्यभिधीयते। (*Ibid*, Sutrasthâna, Chapter XIV).

सप्तशिराशतानि भवन्ति । याभिरिदं शरीरम् आराम इव जलहारिणीभिः केदार इव कुल्याभिरुपस्निह्यते आकुञ्चनप्रसारणादिभिर्विशेषैः। नाभ्यां सर्व्वा निबद्धास्ताः प्रतन्वन्ति समन्ततः। तासां मूलशिराः चत्वारिंशत्तासां वातवाहिन्यो दश पित्तवाहिन्यो दश कफवाहिन्यो दश दश च रक्तवाहिन्यः। तासान्तु वातवाहिनीनां वात स्थानगतानां पञ्चसप्ततिशतं भवति। रक्तवाहिन्यश्च यकृत्प्लीह्नोरेव। तत्र वातवाहिन्यः शिराः एकस्मिन् सक्थ्नि पञ्चविंशतिः। एतेन इतरसक्थिबाहू च व्याख्यातौ। विशेषतस्तु कोष्ठे पृष्ठे चोदरे वक्षसि जत्रुणः ऊर्द्ध्वं एवं रक्तवहाः कफवहाश्च धातूनां पूरणं वर्णं स्पर्शज्ञानमसंशयम्। स्वाः शिराः सञ्चरद्रक्तं कुर्य्याच्चान्यान् गुणानपि (Sârirasthâna, Chapter VIII). द्वितीया (कला) रक्तधरा नाम। तस्यां शोणितं विशेषतस्तु शिरासु यकृत् प्लीह्नोश्च भवति (*Ibid*, Chapter IV). षष्ठी (कला) पित्तधरानाम। चतुर्विधमन्नपानमुपयुक्तमामाशयात् प्रच्युतं पक्वाशयोपस्थितं धारयति। स्रोतस्तद् विज्ञेयं शिराधमनीवर्ज्जितं।...तानि (स्रोतांसि) प्राणान्नोदकरसरक्तमांसमेदोमूत्रपुरीषशुक्रार्त्तववहानि। तत्र प्राणवहे द्वे। तयोर्मूलं हृदयं रसवाहिन्यश्च धमन्यः। उदकवहे द्वे। तयोर्मूलं तालुक्लोम (*Kloma*, gall-bladder) च। तत्र विद्धस्य पिपासा। अन्नवहे द्वे। तयोर्मूलं आमाशयः अन्नवाहिन्यश्चधमन्यः। रसवहे द्वे। तयोर्मूलं हृदयं रसवाहिन्यश्च धमन्यः। रक्तवहे द्वे। तयोर्मूलं यकृत् प्लीहानौ रक्तवाहिन्यश्च धमन्यः। मांसवहे द्वे। तयोर्मूलं स्नायुत्वचं रक्तवाहिन्यश्च धमन्यः।

SECTION 3.

THE NERVOUS SYSTEM IN CHARAKA.

The Nerves. Dhamanis as nerves: The anatomy of the nervous system in Charaka and Susruta, can be more clearly and confidently restored. The Dhamanis that ascend from the heart divide into 30 cords, of which 20, *i.e.*, 10 pairs, are cranial nerves, and the other 10, or 5 pairs, are engaged in conveying vital currents, metabolic fluid, lymph, blood and chyle.

The cranial nerves are: (1) four pairs of sensory nerves carrying sensory impulses from the sense-organs to the heart, *viz.*, the optic, auditory, olfactory, and gustatory nerves and (2) six pairs of motor (or mixed nerves), *e.g.*, three pairs of motor nerves for the eye (Motores oculorum, Pathetic and Abducentes) working the Levator Palpebræ and other muscles of the orbit; one pair of motor nerves for articulation, the hypoglossal; one pair of motor nerves for the larynx, (the Pneumo-gastric), and another pair connected with mammæ and (in the case of the male) the seminal duct. It is further stated that other motor or sensori-motor impulses are carried by some of these cranial nerves, *viz.*, those which produce sighs and sobs, yawning, laughter and hunger. Evidently some of the functions of the pneumogastric and the spinal accessory nerves are intended, as also of the phrenic and other nerves of the cervical plexus.

Of the 30 descending Dhamanis, 10 (or 5 pairs) are conductors of blood, chyle, vital current, metabolic fluid and lymph, and the remaining 20 are spinal nerves (specially the nerves of the sacro-coccygeal and sacral plexuses, if not also of the lumbar plexus). The obliquely branching Dhamanis, so far as they are nerves, comprise the brachial and the lumbar plexus, and divide and sub-divide hundred-fold, thousand-fold, till they ramify into fibrillæ round the pores of the skin. They carry to the heart cutaneous sensations, external as well as internal. A fibril (सूक्ष्मनाडी) is said to be as minute as the thousandth part of a hair (लोम्नः सहस्रभागेन तुल्यासु प्रचरत्यणुः — *Panchadasi*).

ऊर्द्ध्वगाः शब्दरूपरसगन्धप्रश्वासोच्छ्वासविजृम्भितक्षुद्धसितकथितरुदितादीन्विशेषान् अभिवहन्त्यः शरीरं धारयन्ति। तास्तु हृदयमभिप्रतिपन्नास्त्रिधा जायन्ते तास्त्रिंशत्। तासान्तु वातपित्तकफशोणितरसान्। द्वे द्वे वहतस्ता दश। शब्दरूपरसगन्धान् अष्टाभिर्गृह्णीते। द्वाभ्यां भाषते। द्वाभ्यां घोषं करोति। द्वाभ्यां

स्वपिति। द्वाभ्यां प्रतिबुध्यते। द्वे च अश्रुवाहिन्यौ। द्वे स्तनसंश्रिते। ते एव शुक्रं नरस्य स्तनाभ्यां अभिवहतः।

तिर्य्यग्गानान्तु चतसृणां धमनीनां एकैका शतधा सहस्रधा चोत्तरोत्तरं विभज्यन्ते तास्त्वसंख्येयाः।

ताभिरिदं शरीरं गवाक्षितं तासां मुखानि रोमकूप प्रतिबद्धानि। यैः स्वेदमभिवहन्ति रसञ्चापि सन्तर्पयन्ति अन्तर्बहिश्च। तैरेव चाभ्यङ्गपरिषेकावगाहालेपनवीर्य्याणि अन्तःशरीरमभिप्रतिपद्यन्ते। त्वचि विपक्वानि तैरेव स्पर्शसुखमसुखं वा गृह्णाति। तास्तु एताश्चतस्रोध मन्यः सर्वाङ्गगताः सविभागा व्याख्याताः। (Susruta Sârîrasthâna, Chapter IX.)

SECTION 4.

THE NERVOUS SYSTEM AFTER THE TANTRAS—PSYCHOPHYSIOLOGY.

In Charaka and Susruta (as in Aristotle) the heart is the central organ and seat of consciousness. But in the Tantric writings (as in Galen), the seat of consciousness is transferred to the brain or rather the cerebro-spinal system. The Soul (the Jiva) has its special seat within the *Brahmarandhra* above the foramen of Monro and the middle commissure, but traverses the whole cerebro-spinal axis, up and down, along the *Sushumna* (the central canal of the spinal cord). The *Brahmadanda* (vertebral column) contains the *Brahma-Nadi*, the *Sushumna* and the *Manovahâ Nâdi*. The cerebro-spinal axis with the connected sympathetic system contains a number of ganglionic centres and plexuses, (*Chakras, Padmas*) from which nerves (*Nâdis, Śirâs* and *Dhamanis*)* radiate over the head, trunk and limbs.

SECTION 5.

GANGLIONIC CENTRES AND PLEXUSES (SYMPATHETIC-SPINAL SYSTEM).

Beginning with the lower extremity, the centres and plexuses of the connected spinal and sympathetic systems may be described as follows:—

(1) The *Adhâra Chakra*, the sacro-coccygeal plexus, with four branches, nine *Angulis* (about six inches and a half) below the solar plexus (*Kanda, Brahmagranthi*); the source of a massive pleasurable æsthesia, voluminous organic sensations of repose. An inch and a half above it, and the same distance below the membrum virile (*Mehana*) is a minor centre called the *Agni-sikhâ*.

(2) The *Svâdhisthâna Chakra*, the sacral plexus with six branches (पत्राणि, दलानि leaves), concerned in the excitation of sexual feelings with the accompaniments of lassitude, stupor, cruelty, suspicion, contempt.

(3) The *Nâvi kanda* (corresponding to the solar plexus, *Bhânubhavanam*)—which forms the great junction of the right and left sympathetic chains (*Pingalâ* and *Idâ*) with the cerebro-spinal axis.

Connected with this is the *Manipuraka*, the lumbar plexus with connected sympathetic nerves, the ten branches of which are concerned in the production of sleep and thirst, and the expressions of passions like jealousy, shame, fear, stupefaction.

(4) The *Anâhata Chakra*, possibly the cardiac plexus of the sympathetic chain, with twelve branches, connected with the heart, the seat of the egoistic sentiments, hope, anxiety, doubt, remorse, conceit, egoism, etc.

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* The writers of the Yoga and Tantra schools use the term *Nâdî*, by preference, for Nerves. They also mean Cranial nerves when they speak of *Śirâs*, never using the latter term for Arteries, as in the older medical literature.

(5) The *Bhiratisthâna*, the junction of the spinal cord with the medulla oblongata, which, by means of nerves like the pneumo-gastric, etc., regulate the larynx and other organs of articulation.

(6) The *Lalaná Chakra* opposite the uvula, which has twelve leaves (or lobes), supposed to be the tract affected in the production of ego-altruistic sentiments and affections like self-regard, pride, affection, grief, regret, respect, reverence, contentment, etc.

(7) The sensori-motor tract, comprising two Chakras, (*a*) the *Âjná Chakra*, lit. the circle of command (over movements), with its two lobes (the cerebellum), and (*b*) the *Manaschakra*, the sensorium, with its six lobes (five special sensory for peripherally initiated sensations, and one common sensory for centrally initiated sensations, as in dreams and hallucinations).

The *Âjna-vahá Nádis*, efferent or motor nerves, communicate motor impulses to the periphery from this *Âjná Chakra*, this centre of command over movements; and the afferent or sensory nerves of the special senses, in pairs, the *Gandhavahâ Nâdi* (olfactory sensory), the *Rupavahá Nâdi* (optic), the *Śavdavahá Nâdi* (*auditory*), the *Rasavahâ Nádi* (gustatory), and the *Sparasavahá Nadi* (tactile), come from the periphery (the peripheral organs of the special senses) to this *Manaschakra*, the sensory tract at the base of the brain. The *Manaschakra* also receives the *Manovahâ Nâdi*, a generic name for the channels along which centrally initiated presentations (as in dreaming or hallucination) come to the sixth lobe of the *Manaschakra*.

(8) The *Somachakra*, a sixteen-lobed ganglion, comprising the centres in the middle of the cerebrum, above the sensorium;—the seat of the altruistic sentiments and volitional control, *e.g.*, compassion, gentleness, patience, renunciation, meditativeness, gravity, earnestness, resolution, determination, magnanimity, etc.; and lastly

(9) The *Sahasrára Chakra*, thousand-lobed, the upper cerebrum with its lobes and convolutions, the special and highest seat of the *Jiva*, the soul.

गुह्यलिङ्गान्तरे चक्रमाधाराख्यं चतुर्दलम् । परमः सहजः...आनन्दः...स्यादैशानादिदले फलं । स्वाधिष्ठानं लिङ्गमूले षट्पत्रं चक्रमस्यच । पूर्व्वादिषु दलेषु फलानि एतानि प्रश्रयः क्रूरता... मूर्च्छा...अवज्ञा स्यादविश्वासः कामशक्तेरिदं गृहम् । नाभौ दशदलं चक्रं मणिपूरसंज्ञं । सुषुप्तिरत्र तृष्णा स्यादीर्षा...लज्जा भयं घृणा मोहः......क्रमात् पूर्व्वादि दलेषु स्यात् भानुभवनञ्च तत् ।

हृदये अनाहतं चक्रं । दलैर्द्वादशभिर्युतं । लौल्यं कापट्यं वितर्कोऽप्यनुतापिता आशा...चिन्ता ...दम्भोवैकल्ल्यं विवेकोऽहंकृतिस्तथा फलान्येतानि । कण्ठेऽस्ति भारतीस्थानं षोडशच्छदं तत्र प्रणव उद्दीप्तः सप्त स्वरा षड्जादयः । ललनाख्यं घण्टिकायां चक्रं द्वादशपत्रकं । दमोमानस्ततः स्नेहः शोकः खेदश्च सम्भ्रम श्चोर्म्मिः श्रद्धा तोषोऽपराधिता । फलानि ललनाचक्रे भ्रूमध्ये द्विदलं चक्रं आज्ञासंज्ञं फलानि च आविर्भावाः सत्त्वरजस्तमसां । तत्र चास्ति मनश्चक्रं षड्दलं तत्फलानि तु । स्वप्नो रसोपयोगश्च घ्राणं रूपोपलम्भनं

स्पर्शनं शब्दबोधश्च पूर्व्वादिषु दलेषु । ततोऽपि षोड़शदलं सामचक्रं । दलेषु षोडश तस्य कलाः षोडश संस्थिताः । कृपाथ मार्दवं धैर्य्यं वैराग्यं धृतिसम्पदौ हास्यं रोमाञ्चं विनयो ध्यानं सुस्थिरता ततः । गाम्भीर्य्यमुद्यमोऽक्षोभ मौदार्य्यंकाग्रहे क्रमात् । फलान्युद्यन्ति जीवस्य पूर्व्वादिदलगामिनः । चक्रं सहस्रपत्रन्तु ब्रह्मरन्ध्रे । सुषुम्नया ब्रह्मरन्ध्रमारोहत्यवरोहति । जीवः प्राणसमारूढो रज्ज्वा कोलाटिको यथा । ब्रह्मरन्ध्रे स्थितो जीवः सुधया संप्लुतः । आधाराद्द्व्यङ्गुलादूर्ध्वं मेहनाद्द्व्यङ्गुलादधः अग्निशिखा (चक्रं) चक्रात् तस्मात् (आधारचक्रात्) नवाङ्गुलः देहस्य कन्दोऽस्ति । उत्सेधायामाभ्यां

यद्यपीन्द्रियं मनोन साक्षात् प्रयत्नविषयः तथापि मनोवहनाडीगोचरेण प्रयत्नेन मनसि कर्म्म द्रष्टव्यं। नाड्यास्तु त्वगिन्द्रियग्राह्यत्वमङ्गीकर्त्तव्यं। अन्यथा प्राणवहनाडीगोचरेण प्रयत्नेन अशितपीताद्यभ्यवहरणमपि न सम्भवेत्। तत्तदिन्द्रियप्रदेशेन मनःसंयोगमन्तरेण सुखदुःखे न स्यातामेव। यदि मनसि कर्म्म न भवेत् न भवेच्च पादे मे सुखं शिरसि मे वेदना इत्याद्याकारोऽनुभवः।

(Sankara Misra's *Upaskâra*, on Sûtras 14, 15, *Ahnika* 2, Chap. V.)

The Heart. The heart in the older schools is considered to be the seat of waking consciousness. For the heart expands during waking life and contracts during sleep.

Sleep (स्वाप) again is of two kinds (1) dreaming sleep (*swapna, supti*) when the external senses are withdrawn into the heart, but the representative-presentative faculty (मनः, चित्त) wakes, and (2) dreamless sleep (*suṣupti*) when this last faculty is likewise merged in the mere automatic activity of life.

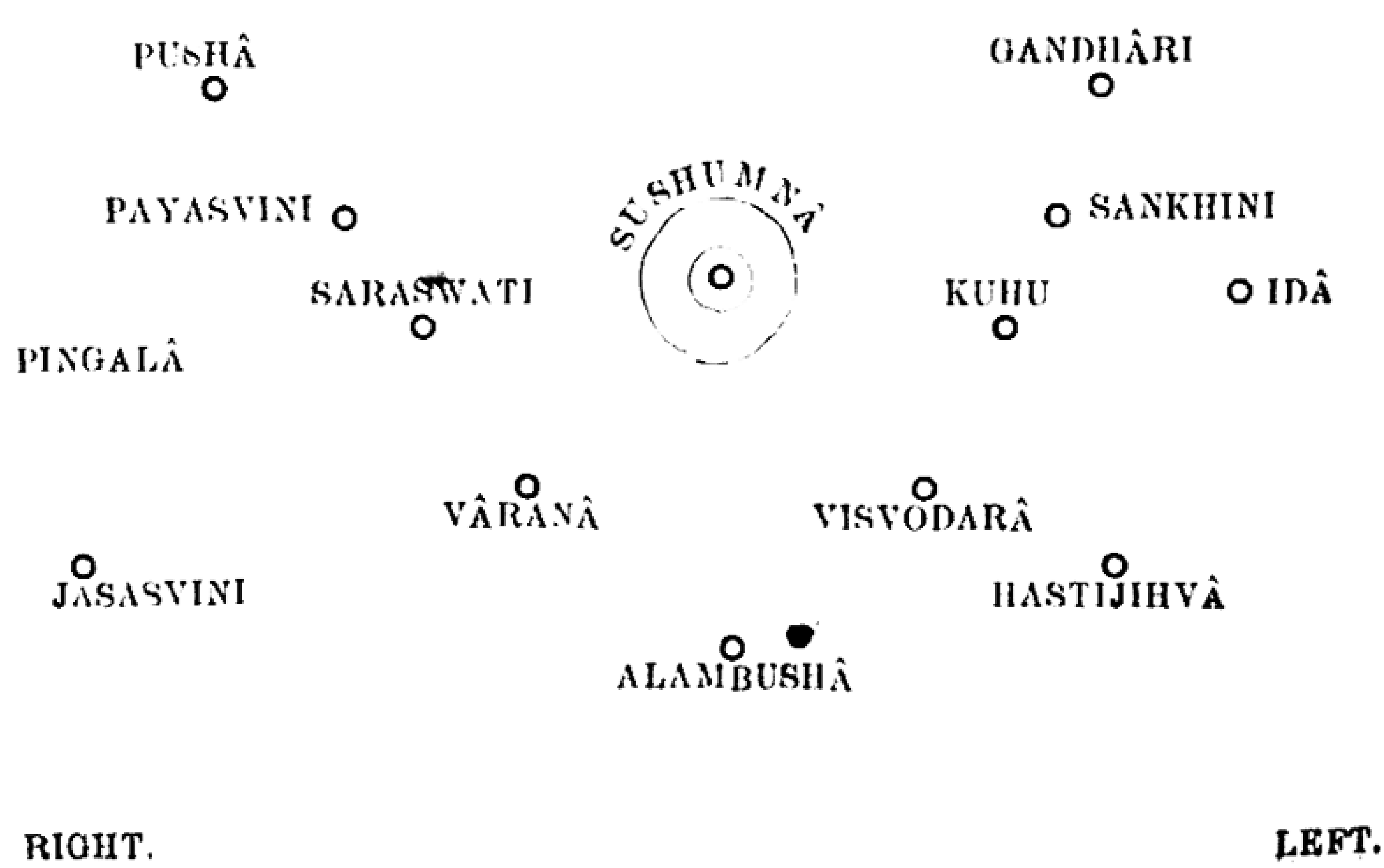
हृदयं पंकजाकृति। सुषिरं स्यादधोवक्त्रं एतच्च चेतनास्थानं। निमीलति स्वपित्यात्मा जागर्त्ति विकशत्यपि। द्वेधा स्वप्नसुषुप्तिभ्यां स्वापः। बाह्येन्द्रियाणि चेत लीयन्ते हृदि जागर्त्ति चित्तं सुप्तिस्तदोच्यते। मनश्चेत् लीयते प्राणे सुषुप्तिः स्यात्तदात्मनः—(*Sangita-ratnâkara*).

SECTION 6.

NERVE CORDS AND FIBRES (SYMPATHETIC-SPINAL SYSTEM).

Nerve-cords and Fibres. Cranial and spinal nerves, and the connected sympathetic nerves:—With the writers on the Yoga, all the *Siras*, and such of the *Dhamanis* as are not vehicles of vital current, metabolic fluid, lymph, chyle or blood, are cranial nerves, and proceed from the heart through the spinal cord to the cranium. These cranial nerves include pairs for the larynx and the tongue, for the understanding and use of speech, for the raising and lowering of the eyelids, for weeping, for the sensations of the special senses, etc.—a confused and unintelligent reproduction of Susruta's classification. But the enumeration of the spinal nerves with the connected sympathetic chain and ganglia, is a distinct improvement on the old anatomists. The following plan attempts to give a rough idea of the relative position of the principal nerves of the sympathetic-spinal system.

TRANSVERSE SECTION.



The *Suṣumná* is the central cord in the vertebral column (ब्रह्मदण्ड, मेरु). The two chains of sympathetic-ganglia on the left and the right are named *Ida* and *Pingala* respectively. The sympathetic nerves have their main connection with *Suṣumná* at the solar plexus (भानुभवन, नाभिचक्र in the कन्द, नाभिकन्द or ब्रह्मग्रन्थि). Of the seven hundred nerve-cords of the sympathetic-spinal system (भूरितरा : Sangîta-ratnâkara), the fourteen most important are :—

(1) *Suṣumná*, in the central channel of the spinal cord.

(2) *Idâ*, the left sympathetic chain stretching from under the left nostril to below the left kidney,—in the form of a bent bow.

(3) *Pingalá*, the corresponding chain on the right.

(4) *Kuhu*, the pudic nerve of the sacral plexus, to the left of the spinal cord.

(5) *Gandhâri*, to the back of the left sympathetic chain,—supposed to stretch from below the corner of the left eye to the left leg. It was evidently supposed that some nerves of the cervical plexus came down through the spinal cord and joined on to the great sciatic nerve of the sacral plexus.

(6) *Hastijihvá*, to the front of the left sympathetic chain stretching from below the corner of the left eye to the great toe of the left foot, on the same supposition as before. Pathological facts were believed to point to a special nerve connection between the eyes and the toes.

(7) *Sarasvati*, to the right of *Suṣumná*, stretching up to the tongue (the hypo-glossal nerves of the cervical plexus).

(8) *Puṣá*, to the back of the right sympathetic chain, stretching from below the corner of the right eye to the abdomen (a connected chain of cervical and lumbar nerves).

(9) *Payasvini*, between Puṣâ and Sarasvatî, auricular branch of the cervical plexus on the right.

(10) *Sankhini*, between Gandhârî and Sarasvatî, auricular branch of the cervical plexus on the left.

(11) *Yaśasvinî*, to the front of the right sympathetic chain, stretching from the right thumb to the right leg (the radial nerve of the brachial plexus continued on to certain branches of the great sciatic).

(12) *Váraná*, the nerves of the sacral plexus, between Kuhu and Jasasvinî, ramifying over the lower trunk and limbs.

(13) *Visvodará*, the nerves of the lumbar plexus, between Kuhu and Hastijihva, ramifying over the lower trunk and limbs.

(14) *Alambuṣá*, the coccygeal nerves, proceeding from the sacral vertebræ to the urino-genitary organs.

(*Vide* Sangîta-ratnákara, स्वराध्याय, पिण्डोत्पत्तिप्रकरणम्, slokas 144-156. Also, the Yogárṇava.)

SECTION 7.

AUTOMATIC AND REFLEX ACTIVITY OF THE ORGANISM —THE FORTY-NINE *VAYUS*.

Charaka describes *Váyu* as that which keeps the machine of the body at work, the prime-mover, the impelling force which sets in motion the organs (including the senses and the mind), which arranges the cells and tissues, and which unfolds or develops the fœtal structure out of the fertilised ovum. Charaka and Susruta notice the five chief *Vâyus* with their functions in the maintenance of the animal life. Susruta mentions

Prána as having its course in the mouth, and concerned in deglutition, hiccough, respiration, etc., *Udána* as concerned in articulation and singing, *Samána* as digesting the food in the stomach in conjunction with the animal heat, *Vyána* as coursing all over the body, driving the chyle and causing the flow of blood and sweat, and *Apána* as having its seat in the intestinal region, and sending down the uro-genital secretions. (Susruta—*Nidánasthana*, Chapter I.)

In the mediæval physiology the number of *Váyus* is given as 49. As in Charaka and Susruta, the *Váyus* are regarded as the moving or impelling forces that work the organism and all its automatic and reflex machinery. The *Ajná-vahá Nádis* (efferent nerves) are only channels for the conduction of commands of the self or the will (आत्मप्रयत्न); the *Váyus*, on the other hand, are forces (or currents) that maintain the automatic, reflex or instinctive activities of the organism. The ten chief *Váyus* with their functions are enumerated thus :

(1) *Prána*, which works the ideo-motor verbal mechanism and vocal apparatus, the respiratory system, the muscles engaged in coughing, sighing, etc.

(2) *Apána*, which ejects the excretions and wastes, the urine, the faeces, the sperm and germ-cells, etc.

(3) *Vyána*, whose work is extension, contraction and flexion of the muscles, tendons and ligaments ; the stored-up energy of the muscles.

(4) *Samána*, the force, which, in conjunction with animal heat, works the machinery of metabolism, in the maintenance of the organic life. It drives or propels the chyle, blood, and every other current (*Srota*) or circulating fluid in the body.

(5) *Udána*, concerned in maintaining the erect posture of the body.

(6) *Naga*, which is concerned in involuntary retching, vomiting.

(7) *Kurma*, which works the automatic movement of the eyelids, winking, etc.

(8) *Krikara*, concerned with the appetites of hunger and thirst.

(9) *Devadatta*, which brings about yawning, dozing, etc.

(10) *Dhanajaya*, which is concerned with coma, swooning, trance.

वायुः तन्त्रयन्त्रधरः प्रवर्तकः चेष्टानां, प्रणेता मनसः, सर्वेन्द्रियाणां उद्योतकः, सर्वशरीरधातुव्यूहकरः, सन्धानकरः शरीरस्य, प्रवर्त्तको वाचः, हर्षोत्साहयोर्योनिः, क्षेप्ता बहिर्मलानां, कर्ता गर्भाकृतीनां। प्राणापानोदानसमानव्यानात्मा (चरक सूत्रस्थान, Chapter XII) तेषां मुख्यतमः प्राणः शब्दोच्चारणनिःश्वासोच्छ्वासकाशादिकारणं, अपानः...अस्य मूत्रपुरीषादिविसर्गः कर्म्म कीर्त्तितं। व्यानः... प्राणापानधृतित्यागग्रहणाद्यस्य कर्म्म च। समानोऽपि अखिलं व्याप्य शरीरं वह्निना सह। द्विसप्तति सहस्रेषु नाडीरंध्रेषु संचरन् भुक्तपीतरसान् सम्यगानयन् देहपुष्टिकृत्। उदानः कर्म्मास्य देहोन्नयनोत्क्रमणादि प्रकीर्त्तितं। त्वगादिधातूनाश्रित्य पंचनागादयःस्थिताः उद्गारादि निमेषादि क्षुत्पिपासादिकं क्रमात्। तन्द्राप्रभृति मोहादि तेषां कर्म्म प्रकीर्त्तितं। (संगीतरत्नाकर)

Cf. the Summary in Raja Sourindra Mohan Tagore's edition of the Sangita Darpaṇa.

शब्दोच्चारणं (वाङ्निष्पत्तिकरणं) निश्वासः उच्छ्वासः (अन्तर्मुखश्वासः) तदादीनां कारणं (साधनं) प्राणवायुः। विण्मूत्रशुक्रादिवहत्वमपानस्य कर्म्म। आकुञ्चनप्रसारणादि व्यानस्य कर्म्म ज्ञेयं। अशितपीतादीनां समतानयनद्वारा शरीरस्य पोषणं समानस्य कर्म्म। उदानवायुः ऊर्द्ध्वनयनमेव अस्य कर्म्म नागादयः नागकूर्मकृकरदेवदत्तधनञ्जयरूपाः पञ्च वायवः। एतेषां कर्म्माणि च यथाक्रमं उद्गारोन्मीलनक्षुधाजननविजृम्भनमोहरूपाणि। (*Sangitadarpaṇa*, Chap. I, Slokas 43-48). Cf. the extract in Sankara.

प्राणः प्रागवृत्तिरुच्छ्वासादिकर्म्मा। अपानः अवागवृत्तिरुत्सर्गादिकर्म्मा। व्यानः तयोः सन्धौ वर्तमानः वीर्यवत्कर्म्महेतुः। उदानः ऊर्द्ध्ववृत्तिः उत्क्रान्त्यादि हेतुः। समानः समं सर्व्वेषु अङ्गेषु यः अन्न-रसान् नयति। इति। (*Sâriraka Bhâṣya*, Chap. II, Pada 4, Sutra 2.)

SECTION 8.

FŒTAL DEVELOPMENT (AFTER SUSRUTA). *

The ovum fertilised by the sperm-cell and developing under the influence of animal-heat forms successive layers and tissues, even as layers of cells and fibres are formed in wood. First are formed seven layers, epithelial and dermal (*Saptatwacha*), then follow the several tissues (*Kalâh*), the flesh, the vascular tissue, the fat and marrow, the lymphatic and (glandular) tissue, the intestinal tissues, the biliary and the seminal vessels. These tissues are regarded by some as modifications of the original dermal layers of the ovum (cf. the layers of the blasto-derm and their relation to the tissues in Embryology). The tissues are supposed to be developed successively, one out of another, by chemical action or metabolism (*pâka*), *e.g.*, chyle is transformed into blood, blood into flesh, flesh into fat, fat into bone, bone (in reality, fat in the bones) into marrow, marrow into sperm-cell. The organs are next formed out of the tissues. The liver, gall-bladder (*kloma*), spleen and lungs are referred to the blood; the intestines to the blood, lymph and bile; the kidneys to the blood and fat; the testicles to the blood, lymph and fat; the heart to the blood and lymph; and the tongue to the lymph, blood and flesh. *Vayu*, with the accompaniment of animal heat, impels the 'currents' (*srotâmsi*) in the system; *Vayu* acting on the flesh gives rise to the muscles; and it is *Vayu*, again, which, with the essence of fat (or marrow), produces the nerves, arteries and tendons (Susruta, *Sarirasthâna*, Chapter IV, and *Sutrasthâna*, Chapter XIV).

The following parts (tissues and organs) in the fœtus are in a special sense modifications of the four organic substances (compounds) contributed by the sperm-cell of the male-parent, hair, nails, teeth, bones, nerves, veins, and arteries, tendons and ligaments, and the sperm-cell; the following of the four organic substances are derived from the mother: skin, blood, flesh, fat, the heart, liver and spleen, kidneys, stomach, intestines, &c. (Charaka, *Sarirasthâna*, Chapter III).

The rudiments of the head and the limbs begin to appear in the third month, and are developed in the fourth; the bones, ligaments, nails, hair, &c. become distinct in the sixth. In the second month the sexual character is indicated by the shape of the fœtus, the shape of a round joint (?) indicating the male sex, and an elongated shape as of a muscle (?) the female sex [Cf. Charaka, *Sârirasthâna*, Chapter IV,—द्वितीयेमासि घन: सम्पद्यते पिण्ड: पेश्यर्बुदं वा। तत्र घन: पिण्ड: पुरुष: स्त्री पेशी अर्ब्बुदं नपुंसक: Chakrapâni notes घन: कठिन:। पिण्डो ग्रन्थ्याकार:। पेशी दीर्घमांसपेशाकारा। अर्बुदं वर्त्तलोन्नत loc cit.

SECTION 9.

HEREDITY.

Transmission of specific characters—what parental characters are transmitted to offspring. The question is raised in Charaka (and earlier still, in the *Brâhmanas*) how specific characters are transmitted,—why the offspring is of the same species as the parental organism, say, the human or bovine species, the equine species (Charaka), or the Asvattha species, Ficus religiosa, (Sankara Brihadâranyaka-bhâṣya). Species (योनय:) may be compared to so many moulds as it were, into which the ovum is cast, even as molten metals are cast in moulds. This is of course only an illustrative analogy; the cause has to be investigated.

* Reproduced from my monograph in Dr. Ray's *Hindu Chemistry*, Vol. II.

Now Charaka and Susruta, following Dhanvantari, hold that the fœtus, or rather the fertilised ovum, develops by palingenesis (instead of epigenesis) ; in other words, all the organs are potentially present therein at the same time and unfold in a certain order. As the sprouting bamboo-seed contains in miniature the entire structure of the bamboo, as the mango blossom contains the stone, the pulp, the fibres, which appear separated and distinct in the ripe fruit, though from their excessive minuteness they are undistinguishable in the blossom, even such is the case with the fertilised ovum.

गर्भस्य हि सम्भवतः...सर्व्वाङ्गप्रत्यङ्गानि युगपत् सम्भवति इत्याह धन्वन्तरिः। गर्भस्य सूक्ष्मत्वात् नोपलभ्यन्ते वंशाङ्कुरवत् चूतफलवच्च तद्यथा चूतफले परिपक्के केशरमांसास्थिमज्जानः पृथक् दृश्यन्ते कालप्रकर्षात्। तान्येव तरुणे नोपलभ्यन्ते सूक्ष्मत्वात्। तेषां केशरादीनां कालः प्रव्यक्ततां करोति एतेनैव वंशाङ्कुरोऽपि व्याख्यातः। एवं गर्भस्य तारुण्ये सर्व्वेषु अङ्गप्रत्यङ्गेषु सत्सु सौक्ष्म्यादनुपलब्धिः तान्येव फलप्रकर्षात् प्रव्यक्तानि भवन्ति। (Susruta, *Sárirasthána*, Chap. III).

The inheritance of specific characters is explained in accordance with this view. Charaka assumes that the sperm-cell of the male parent contains minute elements derived from each of its organs and tissues. (Cf. Darwin's gemmule and Spencer's 'ids'). Sankara similarly states that the sperm-cell (or the seed in the case of a plant) represents in miniature every organ of the parent organism, and contains *in potentia* the whole organism that is developed out of it. (शरीरस्यात्यात्मा शुक्रभूतः अङ्गादङ्गात् सम्भवति। Charaka, Sárirasthána, Chapter IV, cf. Sankara on Brihadáranyaka.)

But if this is so, why are not congenital deformities of the parent, or constitutional diseases contracted in later life, invariably inherited ? Congenital blindness, deafness, dumbness, stammering, lameness, or deformity of the spinal column or of the bony framework, or dwarfish stature, or constitutional diseases like madness, leprosy, or skin diseases in the parent, do not necessarily produce corresponding deformities or infirmities in the offspring. It cannot therefore be that the fertilised ovum represents in miniature every organ and tissue of the parental organisms. The solution of this difficulty Charaka ascribes to Átreya. The fertilised ovum, it is true, is composed of elements which arise from the whole parental organism (समुदायात्मक, समुदायप्रभव), but it is not the developed organs of the parents, with their idiosyncracies or acquired characters, that determine or contribute the elements of the sperm-cell (or seed). The parental Vija (seed, germ-plasm) contains the whole parental organism in miniature (or *in potentia*), but it is independent of the parents' developed organs, and is not necessarily affected by their idiosyncracies or deformities. In fact, the parental Vija (seed, germ-plasm) is an organic whole independent of the developed parental body and its organs. In the parental Vija, an element representing a particular organ or tissue may happen (for this is accidental, दैव) to be defective or undeveloped, or otherwise abnormally characterised, and in this case the corresponding organ or tissue of the offspring will be similarly characterised. When constitutional diseases, acquired in later life, are found to be inherited, Átreya would suppose that the Vija of the parent has been affected, and this would explain the fact of the inheritance. In the case of leprosy, for example, it is transmitted to the offspring, only when the germ-plasm (the Vija or the fertilised ovum) is infected with the virus of the disease by reason of the leprosy of the parent (*vide* Charaka's report of Átreya's theory, Sárirasthána).

एवमयं नानाविधानां एषां गर्भकराणां भावानां समुदायादभिनिवर्त्तते गर्भः। यद्ययमेषां नानाविधानां गर्भकराणां भावानां समुदयादभिनिवर्त्तते गर्भः कथमयं सन्धीयते। यदि चापि सन्धीयते कस्मात् समुदायप्रभवः सन् गर्भो मनुष्यविग्रहेण जायते मनुष्यश्च मनुष्यप्रभवः उच्यते। ....तत्र चेत् इष्टमेतत्यस्मात् मनुष्यमनुष्यप्रभवः तस्मादेव मनुष्यविग्रहेण जायते यथा

गौर्गोप्रभवः यथा चाश्वः अश्वप्रभवः इत्येवं। यदुक्तं अग्रे समुदायात्मक इति तदयुक्तं । यदि च मनुष्यः मनुष्यप्रभवः कस्मात् जडान्धकुब्जमूकवामनमिन्मिनव्यङ्गोन्मत्तकुष्ठकिलासिभ्यो जाताः पितृसदृशा न भवन्ति *et seqq*...

यच्चोक्तं यदि च मनुष्यो मनुष्यप्रभवः कस्मान्न जडादिभ्यो जाताः पितृसदृशरूपा न भवन्तीति तत्रोच्यते यस्य यस्यहि अङ्गावयवस्य बीजे बीजभाव उपतप्तो भवति तस्य तस्य अङ्गावयवस्य विकृतिः उपजायते। नोपजायते च अनुपतापात् तस्मात् उभयोपपत्तिरप्यत्र। सर्वस्य च आत्मजानीन्द्रियाणि तेषां भावाभावहेतुर्दैवं। तस्मान्नैकान्ततो जड़ादिभ्यो जाताः पितृसदृशरूपा भवन्ति। (चरक शारीरस्थान तृतीयपरिच्छेद)

दम्पत्योः कुष्ठबाहुल्याद् दुष्टशोणितशुक्रयोः। यदपत्यंतयोर्जातं ज्ञेयं तदपि कुष्ठितं ।

N. B.—The seventh tissue (the *Sukradhari* kalâ, sperm-bearing or reproductive) contains the parental Vija, which is a minute organism (समुदायात्मक) deriving its elements from the parental organs, but distinct from the latter, and independent of their peculiarities, and it is the combination and characters of these constituent elements of the parental Vija in the reproductive tissue, that determine the physiological characters and predispositions of the offspring. We may call this Âtreya's *germ-plasm theory*, for it is an advance on the conception of gemmules and of ids, but in Âtreya's version, the germ-plasm is not only representative of the somatic tissues, but also generates and is generated by the latter. This mutual interaction of the 'germ-plasm' and 'somatic tissues' is a distinctive feature of Âtreya's hypothesis, the value of which will be differently estimated by different schools of biologists.

I may also add that the continued identity of the germ-plasm बीज from generation to generation, though it follows as a corollary from this doctrine of a distinct reproductive tissue, even when conceived to be affected by somatic processes, as Âtreya and Charaka conceive it to be, is nowhere expressly deduced. On the other hand, Âtreya and Charaka emphasise the influence of abundant or defective nutrition, and of the (chemical) constitution of the food, etc., on the characters of the Vija in the reproductive tissue, especially as regards the sexual character, the stature, and the colour pigment (वर्ण) of the offspring. But though the influence of nutrition on the Vija is thus freely admitted in a general way, it is expressly stated that the peculiar characters or idiosyncrasies of the elements that combine to form the Vija must be regarded as a matter of chance (दैव), in other words, the truly congenital variations are accidental.

SECTION 10.

THE SEX QUESTION.

Influence of nutrition on the ovum especially as regards the sex, stature and colour-pigment of the resulting offspring;—In a general way, ghee and milk for the male, and oil and beans for the female parent, are favourable to the Vija. The sexual character of the offspring depends in part on a periodicity to which the life-history of the ovum in the female parent is conceived to be subject—a law of alternate rhythmic change (not unlike what we now know to regulate the development of several orders of bacteria or unicellular organisms), a law, under which the fertilisation of the ovum on the fourth day after the menstrual discharge, or on the alternate days succeeding, is favourable to the fœtus developing the male sexual character, and on the fifth, seventh, and alternate following days, to the fœtus assuming the female sex. The *Prayoga-chintámani* states that the latter occurs on even days, and the former on odd days. Another factor is the relative predominance of the sperm and the germ-cells in the fertilised ovum. Excess of the sperm-cell produces the male, that of the germ-cell the female. For male offspring of tall stature, fair complexion and energetic temperament, wheat pulp with

honey, ghee (clarified butter), and milk should be taken by the female parent Generally speaking, the adoption of the food, clothing, habits, of people of any particular clime are supposed to be favourable to the production of their characteristic stature and complexion. As to sex, the fœtus for a time remains indeterminate, and then takes on a definite male or female character, but before this stage is reached, the development of the sex can be modified to some extent by food and drugs (पुंसवनमौषधं). As for the colour-pigment, it is the animal heat (तेजोधातु) which is its source; but where the *Âkâsa* and *Ap*-particles predominate (in the food), the animal heat (of the metabolic processes) produces a fair complexion; where earth and Vâyu particles predominate in the food, blackness is the result, and where the different *bhutas* are combined in nearly equal proportion in the food, the metabolic heat produces a dark pigment. In the later literature, ghee (clarified butter) habitually taken by the female during gestation is supposed to produce a fair complexion; and rice (or wheat) and salads, a dark complexion. Charaka also holds that mental impressions of the parent are powerful factors in the determination of the characters of the offspring.

यथाहि बीजमनुपतप्तं उप्तं स्वां स्वां प्रकृतिं अनुविधीयते व्रीहिर्वा व्रीहित्वं यवोवायवत्वं तथा स्त्रीपुरुषौ अपि यथोक्तं हेतुविभागं अनुविधीयते। ...तस्मादापन्नगर्भां स्त्रियमभिसमीक्ष्य प्राग् व्यक्तीभावात् गर्भस्य पुंसवनमौषधमस्यै दद्यात्।...स्नानात् प्रभृति युग्मेषु अहःसु संगमेतां पुत्रकामौ तौ अयुग्मेषु दुहितृकामौ।...उपाचरेच्च मधुरौषधसंस्कृताभ्यां घृतक्षीराभ्यां पुरुषं स्त्रियन्तु तैलमाषाभ्यां। सा चेत् एवमाशासीत बृहन्तमवदातं हर्य्यक्षं ओजस्विनं शुचिं सत्त्वसम्पन्नं पुत्र मिच्छेयमिति। शुद्धस्नानात् प्रभृति अस्यै मधुसर्पिर्भ्यां संसृज्य श्वेतायाः गोः स्वरूपवत्सायाः पयसा आलभ्य राजते कांस्ये वा पात्रे काले काले सप्ताहं सततं प्रयच्छेत् पानाय। ...या येषां जनपदानां मनुष्यानां अनुरूपं पुत्रमाशासीत सा तेषां जनपदानां मनुष्याणां आहारविहारोपचारपरिच्छदान् अनुविधीयस्व इति वाच्या स्यात्।

न खलु केवलमेतदेव कर्म्म वर्णाणां वैशेष्यकरं अपितु तेजोधातुरपि उदकान्तरीक्षा धातुः प्रायः अवदातवर्णकरो भवति। पृथिवीवायुधातुः प्रायः कृष्णवर्णकरः। समसर्वधातुः प्रायः। श्यामवर्णकरः। आधिक्ये रेतसः पुत्रः। कन्यास्यात् आर्त्तवेऽधिरक्'।

SECTION 11.

LIFE.

The question of the vital force or vital principle :—

These activities maintain the life of the organism, but what is this life itself?

The *Chârvâkas* (materialists and sensationalists) answer that life (as well as consciousness) is a result of peculiar chemical combinations of dead matter (or the four elements) in organic forms, even as the intoxicating property of spirituous liquors results from the fermentation of unintoxicating rice and molasses. Similarly, the instinctive movements and expressions of new-born babes (sucking, joy, grief, fear, etc.) can be explained mechanically as due to external stimuli as much as the opening and closing of the lotus and other flowers at different hours of the day (or night), or the movement of iron under the influence of the loadstone. In the same way, the spontaneous generation of living organisms is frequently observed, *e.g.*, the case of animalcules which develop in moisture or infusions, especially under the influence of gentle warmth (स्वेदज, उष्मज, दंशमशका.यः), or of the maggots or other worms which, in the rainy season, by reason of the atmospheric moisture, are developed in the constituent particles of curds and the like, which begin to live and move in so short a time.

(Gotama, in his *Sutras*, reports the Chârvâka explanation of instinctive emotional expressions in babes: पद्मादिषु प्रबोधसम्मीलनवत् तद्विकार: Sutra 20, Ahnika I, Chapter III, cf. the explanation of the movement preparatory to sucking;– अयसो ऽयस्कान्ताभिगमनवत् तदुपसर्पणं Sutra 23, *ibid.* Jayanta, in the *Nyâya-manjari*, reports the Chârvâka explanation of consciousness (and life).

मदशक्तिवत् विज्ञानं। पृथिव्यादीनि भूतानि चत्वारि तत्त्वानि। तेभ्य एव देहाकारपरिणतेभ्य: मदशक्तिवत् चैतन्यमुपजायते।

For spontaneous generation, *vide* Jayanta's report.

वर्षासुच स्वेदादिना अनतिदवीयसैव कालेन दध्याद्यवयवा एव चलन्त: पूतनादिक्रिमिरूपा उपलभ्यन्ते

(*Nyâya-manjari*, Ahnika 7, भूतचैतन्यपक्ष:)

The Sânkhya view of consciousness—Reply to the materialists—

The intoxicating power in liquor is a force, *i.e.*, a tendency to motion, and this is the resultant of the tendencies (or subtile motions) present in the particles of the fermented rice, molasses, etc. A motion, or a tendency to motion, can in this way be the resultant of several other motions or tendencies. But consciouness (चैतन्य) is not a motion, and cannot be the resultant of (unconscious) natural forces or motions. Neither can the consciousness of the Self, or of the organism as a whole, be supposed to be the resultant of innumerable consciousnesses vested in the innumerable constituent particles of the body. One central abiding intelligence is a simpler and therefore more legitimate hypothesis than an assemblage of consciousnesses latent in different Bhutas or particles, cf. Vijnânabhiksu's comment on the Sutra, मदशक्तिवच्चेत् प्रत्येकपरिदृष्टे सांहत्ये तदुद्भव: (Sutra 22, Chapter III.)

ननु यथा मादकताशक्ति: प्रत्येकद्रव्याव्यावृत्तिरपि मिलितद्रव्ये वर्त्तते एवं चैतन्यमपि स्यादिति चेन्न प्रत्येकपरिदृष्टे सति सांहत्ये तदुद्भव: सम्भवेत्। प्रकृते तु प्रत्येकपरिदृष्टत्वं नास्ति...ननु समुच्चिते चैतन्यदर्शनेन प्रत्येकभूते सूक्ष्मचैतन्यशक्तिरनुमेया इति चेन्न। अनेकभूतेषु अनेकचैतन्यशक्तिकल्पनायां गौरवेण लाघवादेकस्यैव नित्यचित्स्वरूपस्य कल्पनौचित्यात्। Cf. also भूतगतविशेषगुणानां सजातीयकारणगुणजन्यतया कारणे चैतन्यं विना देहे चैतन्यासम्भवात्। *ibid.*

मद्ये मदशक्तिर्न गुण:। मद्यारम्भकानां पिष्टगुडमध्व* दीनां यत् यस्य कर्म तै: कर्म्मभिरारब्धं स्वस्वकर्म्मविरोध कर्म्म यदुच्यते प्रभाव इति। चैतन्यादिकं न कर्म्म।

(Vijnânabhikṣu—*Pravachanabhâshya*, Sutra, 22 Chapter III).

Cf. also Gangâdhara's *Jalpakalpataru*, (1867, Calcutta)—explaining the distinction between property (गुण) and power (प्रभाव), a technical term in medicine, which is a form of motion (कर्म्म) *Sutrasthâna*, Jalpakalpataru.

The Sânkhya view of Prâṇa (life):—

Life, according to the Sânkhya, is not a *Vâyu* (biomechanical force) nor any mere mechanical motion resulting from the impulsion of Vâyu. The five vital operations, Prâṇa, Apâna, etc., are called *vâyus*, but this is only a metaphor. Life is in reality a reflex activity, a resultant of the various *concurrent* activities of the *Antahkaraṇas*, *i.e.*, of the sensori-motor (ज्ञानेन्द्रिय कर्म्मेन्द्रिय), the emotional (मन:) and the apperceptive reactions of the organism (for some add अहङ्कार)

Vijnânabhikṣu notes that this explains the disturbing (elevating or depressing) effect on the vitality, of pleasurable or painful emotions like love (काम), which are activities of *Manas*, one of the *Antahkaraṇas* concerned in the reactions of the living organism. On the Sânkhya view, then, *Prâṇa* or life is not a Vâyu, nor is it evolved from the Bhutas, inorganic matter. Prâṇa is only a complex reflex activity (सम्भूयैका वृत्ति) resulting from the operation of the psycho-physical principles or forces in the organism. (*cf.* Sankara

reporting the Sânkhya view—करणानि नियतवृत्तयः सन्तः सम्भूयैकां प्राणाख्यां वृत्तिं प्रतिपद्यन्ते। *Sârîraka-bhâṣya*, Chapter II, Pada 4, Sûtra 9) सामान्यकरणवृत्तिः प्राणाद्या वायवः पञ्च। (Isvarakriṣṇa, Kârikâ).

Also Sûtra 31, Chapter II, where Vijnânabhikṣu notes :—

वायुवत् सञ्चारात् वायवः प्रसिद्धाः। अस्माकं नायं नियमः यदिन्द्रियवृत्तिः क्रमेणैव भवति नैकदा। जातिसाङ्कर्य्यस्य अस्माकं अदोषत्वात्। सामग्रीसमवधाने सति अनेकैरपीन्द्रियैः एकदैकवृत्त्युत्पादने बाधकं नास्ति। Vijnânabhikṣu, *Pravachana-bhâṣya*, Chapter II, Sutras, 31, 32. मनोधर्मस्य कामादेः प्राणक्षोभतया सामानाधिकरण्येनैव औचित्यात्। *ibid.*

The Vedântic view of Prâṇa.

The Vedântists are believers in an independent vital principle. They agree with the Sânkhyas in holding that *Prâṇa* is neither a *Vâyu*, nor the operation of a Vâyu. But neither is Life a mere reflex or resultant of concurrent sensori-motor, emotive and apperceptive reactions of the organism. You may put eleven birds in a cage, and if they concurrently and continually strike against the bars of the cage in the same direction, the cage may move on under this conjoint action. But the sensory and motor activities cannot in this way originate the vital activity of the organism. For the deprivation of anyone or more of the senses does not mean a deprivation of life, and above all there is this radical distinction : there is sameness of kind (समतीयत्व) between the motions of the individual birds and the resultant motion of the cage, but the sensations do not explain life. *Life* (Prâṇa) must therefore be recognised as a separate principle, just as the *Manas* and the *Antahkaraṇas* generally are in the Sânkhya Philosophy. Life is a sort of subtle rarefied 'ether-principle' (अध्यात्मवायु) pervasive of the organism,—which is not gross Vâyu, but is all the same subtilised matter, like the Manas itself, for, in the Vedânta, everything other than the Self (आत्म) is "material"(जड)

This Life is prior to the senses, for it regulates the development of the fertilised ovum which would putrefy if it were not living, and the senses with their apparatus develop subsequently out of the ovum (न वायुक्रिये पृथगुपदेशात्) Chapter II, Pada 4, Sutra 9, *vide* Sârîraka Bhâṣya, Sankara,—also, Vâchaspati Misra, Bhâmatî :—

सिद्धान्तस्तु न सामानेन्द्रियवृत्तिः प्राणः। स हि मिलितानां वा वृत्तिर्भवेत् प्रत्येकं वा। न तावत् मिलितानां। एकद्वित्रिचतुरिन्द्रियाभावे तदभावप्रसङ्गात्। नो खलु चूर्णहरिद्रासंयोगजन्माऽरुणगुणस्तयोरन्यतराभावे भवितु मर्हति। न च वहुविष्टिसाध्यं शिविकोद्वहनं द्वित्रिविष्टिसाध्यं भवति। न च त्वगेकसाध्यं। तथा सति सामान्यवृत्तित्वानुपपत्तेः। अपि च यत् सम्भूयकारकाणि निष्पादयन्ति तत् प्रधानव्यापारानुगुणावान्तरव्यापारेणैव। यथा वयसां प्रातिस्विको व्यापारः पिञ्जरचालनानुगुणः। इहतु श्रवणाद्यवान्तरव्यापारोपेतः प्राणा न सम्भूय प्राण्युरिति युक्तं प्रमाणाभावादत्यन्तविजातीयत्वाच्च श्रवणादिभ्यः प्राणनस्य। *** तस्मादन्यो वायुक्रियाभ्यां प्राणः। *** वायुरेवायमध्यात्ममापन्नः मुख्योऽपि प्राणः। Sankara, *ibid*. *Cf.* also, ज्येष्ठश्च प्राणः शुक्रनिषेककालादारभ्य तस्य वृत्तिलाभात्। नचेत् तस्य तदानीं वृत्तिलाभः स्यात् शुक्रं पूयेत न सम्भवेद्वा श्रोत्रादीनान्तु कर्णशष्कुल्यादिस्थानविभागनिष्पत्तौ वृत्तिलाभान्न ज्येष्ठत्वं। Sankara, on Sutra 9, Pada 4, Chapter II.

CHAPTER IV.

HINDU IDEAS ON MECHANICS (KINETICS).

SECTION 1.

ANALYSIS OF MOTION.

In his Bhâṣya on the Vaiśeṣika Aphorisms written probably in the third or fourth century of the Christian era, if not earlier, Praśastapâda begins the Section on Motion (कर्म्म ग्रन्थ) with the definition of *karma* (motion, lit. work) as the unconditional cause of conjunction and disjunction, *i.e.*, of change of place in a particle (संयोग विभाग निरपेक्ष कारणं). He regards Karma (motion) as instantaneous (क्षणिक) in its simplest form, distinguishing it from *Vega* (impressed motion, momentum) which is a persistent tendency, Sanskâra, and implies a series of motions. Accordingly, in one and the same particle, there can be only one motion (karma) at any given moment, since its change of place at that moment is one and definite (एकदा एकस्मिन् द्रव्ये एकमेव कर्म्म वर्त्तते। प्रशस्तपादभाष्य, कर्म्म पदार्थनिरूपणं). The supposition of two (instantaneous) motions in the same particle is superfluous. They may be so opposed as to neutralise each other, in which case the particle would be at rest. If they are not so opposed, and motion (*i.e.*, an instantaneous change of place) follows, then, since this change of place is a definite change, one motion would be sufficient to account for it, and the hypothesis of two motions would be meaningless (अथ अविरुद्धकर्म्मद्वयसमावेशः तदा एकस्मादेव उपपत्तेः द्वितीय कल्पनावैयर्थ्यम् – Praśastapâda). One and the same motion can affect only one particle, as the changes of place of different particles must be different (एकं कर्म्म न अनेकत्र वर्त्तते— *Ibid.*)

Now motion is always marked by a certain direction (दिग्विशिष्टकार्यारम्भकत्वस्य विशेषः):

(i) The successive motions of a particle may be in the same direction (rectilinear) *e.g.*, (*a*) upward or downward vertical motion, as in throwing upwards or downwards in the case of objects moved by volition directly or indirectly (उत्क्षेपणं, अपक्षेपणं), or (*b*) other forms of rectilinear motion, contraction, dilation (आकुञ्चनं, प्रसारणं) ;–

or (ii) the directions of the successive motions may be different as in curvilinear motion (यदनियत दिक्प्रदेश संयोगविभागकारणं तद्गमनं), *e.g.*, भ्रमण (rotatory motion), स्पन्दन (vibratory motion), etc. All these are varieties of Gamana (गमन, curvilinear motion) (उत्क्षेपणादिशब्दैः अनवरुद्धानां भ्रमणपतनस्पन्दनादीनां अवरोधार्थं गमनग्रहणं कृतम्.—*Ibid*–cf. Sankara Misra, गमनत्वं च जातिविशेषः भ्रमणरेचनस्यन्दनोर्द्ध्व ज्वलनन मनोत्रमनादिष्वपि). In another sense, all kinds of motion in material (inanimate) objects, whether rectilinear or curvilinear, are called Gamana (गमन)

(एतत् पञ्चविधमपि कर्म्म शरीरावयवेषु च तत् सम्बद्धेषु तत् प्रत्ययं असत् प्रत्ययं च। यत् अन्यत् अप्रत्ययमेव तेषु अन्येषु च तत् गमनमिति Praśastapâda, कर्म्मग्रन्थ)।

Single particles, then, may have a serial motion when particles (अवयवाः) combine to form a body (अवयवी), they may move continuously in a straight line, in which case the body is said to move in that direction (अवयविक्रियाया यावदवयवक्रिया नियतत्वात् action the body is determined by the action of the constituent parts taken together). But different particles may move in different directions, or again, the particles may have a curvilinear motion, and in such cases it appears as if different motions are impressed on the body, *e.g.*, the falling leaf driven by the wind may have a rotatory or vibratory motion (भ्रमण, स्पन्दन) and a vertical downward motion (पतन) at the same time. Here each particle of the leaf taken separately has only one motion or change of place at the same moment, but from the point of view of the observer द्रष्टा, the particles

have a rotatory or vibratory motion in one relation, and the leaf as a whole has a downward motion in another relation. The motion at any instant is really one, but for convenience of analysis we consider the rotatory change of place as separate from the change of place in the downward direction, एकस्मिन् कर्म्मणि युगपत् द्रष्टृणां भ्रमणपतनप्रवेशन प्रत्यया कथं भवन्ति । अत्र भ्रम अवयवावयविनो दिग्विशिष्टसंयोग विभागानां भेदात्—*Ibid.*

SECTION 2.

MOTION CONSIDERED IN RELATION TO ITS CAUSES.

Various kinds of motion are observed :—

I. Movements which are not caused by contact with matter :—

(1) Movements caused by volition (प्रयत्न) *e.g.*, the movement of the hand.

(2) Movement, as of a falling body. This is caused by gravity (गुरुत्व) which in the astronomical treatises of Âryabhata, Brahmagupta and Bhâskara, is ascribed to the attraction (आकर्षण, pulling force) exercised by the Earth on a material body. The force of gravity may be counteracted by volition (विधारक, प्रयत्न) as in holding of the hand, or by contact, as when a body rests on a support, or by *vega* (वेग), impressed motion, as in the flying arrow which is kept from falling by the motion impressed on it.

(3) Motion of fluids, as the downward flow in a stream (स्यन्दन). This is due to fluidity (द्रवत्व) which is a characteristic property of certain kinds of atoms, in some cases original, in others produced by the contact of these atoms with the atomic particles of heat (*e.g*, in the fire). But Sankara Misra points out that this property, fluidity, is only a concomitant condition (असमवायिकारण), the efficient cause (निमित्तकारण) is even in this case gravity (गुरुत्व) in the particles of the fluid. यत्तूर संसरणंस्यन्दनं तत् द्रवत्वात् असमवायि कारणात् उत्पद्यते, गुरुत्वात् निमित्तकारणात् असमवायिकारणेषु. (Sankara Misra, Upaskâra, on Sutra 4, Ahinka 2, Chap. V, of the Vaiśeṣika Sutras).

(4) Certain motions, not due to material contact, of which the mechanical causes are unknown and which may be ascribed to the universal final cause, Adriṣta (अदृष्ट,) *e.g.*, the first motion in atoms at the beginning of creation, the upward motion of fiery particles or atoms, and the oblique motion of gaseous particles, *vâyu*, (वायु), the movement of iron towards the magnet, capillary motion (अभिसर्पण) as of liquid particles from the root to the stem of a plant. The upward motions (आरोहण) of water-particles in evaporation and in boiling do not require the hypothesis of Adriṣta, as these are caused by the pressure of heat corpuscles (तेज: परमाणु) and the contact with air particles (नोदनापीडनात् संयुक्तसंयोगाच्च—Vaiśeṣika Sutra, Chap. V, Ahnika 2).

MEANING OF ADRIṢTA (अदृष्ट)

Adriṣta (lit. unseen) stands for 'unknown cause' or 'unexplained Nature' in the earlier Vaiśeṣika writers. Several classes of cases falling under Adriṣta are distinguished, *e.g.*

(1) the operation of merit and demerit (धर्म्म) and (अधर्म्म), a transcendental cause, which has to be posited in explaining the conjunctions and disjunctions of souls with their organic vehicles (bodies), which cannot be ascribed to natural causes, but presuppose the law of karma, or the operation of moral causation, as super-imposed on the natural order,

(2) various kinds of motion, in the different classes of elements, *e.g.*, their natural modes of operation, such as the dispersion of Vâyu (air, gas), the upward motion of fire, the attraction of the needle by the magnet, etc., motions which serve the ends

of Creation and of created beings (उपकारकं अपकारकं). Such natural properties must be **ascribed to Adriṣta, final causality** (उपकारापकारसमर्थं अदृष्टकारितं), provided the *cause cannot be ascertained by observation or inference.*

1. लब्धवृत्तिभ्याम् धर्म्माधर्म्माभ्याम् कर्म्मोत्पद्यते—*Ibid.* अपसर्पणकर्म्म उपसर्पणकर्म्म, etc.

2. एवमन्यदपि महाभूतेषु यत्प्रत्यक्षानुमानाभ्यामनुपलभ्यमानकारणं उपकारापकारसमर्थं च भवति तदपि अदृष्टकारितं—*Ibid.*

Jayanta in the Nyâya-Manjari notes that Adriṣta is resorted to in explanation of observed phenomena only when these cannot be derived in any way from the operation of known causes—यदि अदृष्टमन्तरेण दृष्टं न सिद्ध्यति काममदृष्टं कल्प्यताम् अन्यथा अपितु तदुपपत्तौ किं तदुपकल्पनेन। दृष्टसिद्ध्यर्थं हि अदृष्टं कल्प्यते न तु दृष्टविघाताय। न्यायमञ्जरी—Ahnika I.

Similarly, Jayanta notes that, when anything is put down as natural (स्वाभाविक), we may mean either that it has no cause or no uniform cause, or no known cause. Of these, the first two alternatives must always be dismissed. And 'natural' can only mean something of which no cause has yet been ascertained (स्वाभाविकं नाम किमुच्यते किमहेतुकं अविज्ञातहेतुकं अनियतहेतुकं वा। न तावदहेतुकं कार्य्यं सम्भवति............नापि अनियतहेतुकं कार्य्यं किञ्चिदस्ति - न्यायमञ्जरी – चार्वाकमतनिरास।

This sound interpretation of Adriṣta was afterwards obscured. In modern writers of the Nyâya-Vaiseṣika School, physical and mechanical ideas have suffered a set-back, and even the formation of the hailstone is ascribed to the operation of moral causes (धर्म्माधर्म्म).

II. We come now to motions produced by contact (संयोग). Such motions may be classed as follows, according to the nature of the contact originating them :—

(1) Motion due to direct contact with a body exercising continued pressure (नोदन) e.g., the motion of an object pushed or pulled by the hand, the motion of the mud under heavy stones, the motion of the arrow due to the pressure exercised by the bowstring, the motion of the bowstring due to the pressure of the elastic bow as it recovers its original shape, the motion of clouds, of volumes of dust, of balloons, sailing vessels, and other vehicles, under the impelling force (pressure, नोदनः प्रेरण) of the wind, etc. वायुर्मेघादिप्रेरणधारणादि समर्थः (Prasastapâda, वायुनिरूपण--मेघादीत्यादिपदेन यानपोतादिपरिग्रहस्तेषामपि वायुना प्रेर्य्यमाणत्वात्। Sridhara मेघादीति आदिग्रहणात् विहायसानां विमानादीनां (balloons in the sky) भीमादीनां च पानपात्रपांशुपटलादीनां जलानलयोश्च परिग्रहः (Udayâna, Kiraṇâvalî, वायुनिरूपणम्)

N.B. Udayana makes a similar reference to balloons filled with gas or smoke (धूमापूरित चर्म्मपुटकं) in discussing the opinion that air has weight (Kiraṇâvalî, वायुनिरूपणम्) These passages show that balloons were known in Udayâna's time (974 A. D.—*vide* उदयन, Lakṣanâvali).

(2) Motion due to direct contact for an instant with a body that strikes and produces an impact (अभिघात) *e.g.,* in the cases of a stone falling against a hard object (पाषाणादिषु निष्ठुरेःवस्तुनि अभिपतितेषु--Sridhara), the potter's rod striking the wheel, the mortar struck against the pestle. Instantaneous disjunction is necessary to impact. If there is continued contact, the result is pressure (नोदन,). In some cases there may be disjunction (*i.e.,* a rebound) after continued pressure (यत्र अभिघातकं द्रव्यं भूप्रदेशं अभिहत्य किञ्चिदधो नीत्वा उत्पतति-श्रीधर—न्यायकन्दली).

(3) Motion due to direct contact with an elastic body which exercises a moving force by means of its elasticity (स्थितिस्थापकत्व) in the act of restitution of the original form, (यथा स्थितं स्थापयति) *e g.,* the motion of the bow-string due to the force exercised by the piece of bamboo (the bent bow). This force of restitution in an elastic body is a kind of sanskâra,

i.e., persistent tendency (धनुशाखाशृङ्गदन्तास्थि सूत्रवस्त्रादिषु भुग्नसम्वर्तितेषु स्थितिस्थापकत्वकार्य्यं संलक्ष्यते—प्रशस्तपादभाष्य bows, twigs, tooth-bones, horn, thread, cloth, etc., are noted as elastic).

(4) Motion due to contact with a body which is itself in contact with another which possesses Vega (impressed motion or momentum). (वेगवद्द्रव्यसंयुक्तसंयोग) This is the fact of the transmission of pressure or moving force, and the consequent production or communication of motion, as for example, in the pulling of an object by means of a string, the pushing of the potter's wheel by the potter's rod, etc.

SECTION 3.

CAUSE OF MOTION, OR FORCE.

Force is of the following kinds :—

1. Continued pressure (नोदन)
2. Impact (अभिघात).
3. Persistent tendency (संस्कार) of which there are two kinds—(*a*) Vega (वेग impressed motion, momentum), the persistent tendency to motion in a moving body, and (*b*) the tendency to restitution of shape in an elastic body (स्थितिस्थापकसंस्कार).

N. B.—The metaphysical *sanskâra* (भावना) is here omitted.

4. Transmitted force, as in pulling by a string, pushing by a rod, etc.
5. Gravity.
6. Fluidity.
7. Volition.
8. Adriṣta, comprising various unknown agencies.

In every case of motion produced by contact, Vega is a contributary cause, as the body originating the motion must possess Vega (impressed motion, momentum).

The concept of Vega (वेगाख्य संस्कार).

A motion (karma) being conceived as a change of place in a particle is held to be incapable of producing another motion ; but the pressure, impact or other force which produces the first motion produces through that motion a *sanskâra* or persistent tendency to motion (*vega*), which is the cause of continued motion in a straight line, *i.e.*, in the direction of the first motion (नियतदिक् क्रिया प्रबन्धहेतु: यत् दिगाभिमुख्येन क्रियाग्वेगो जन्यते तत् दिगभिमुखतयैव क्रिया सन्तानस्य हेतुरिति—श्रीधर, न्याय-कन्दली संस्कारनिरूपणम्)

The Vaiśeṣikas accept one *sanskâra* (impressed motion, momentum) lasting till the cessation of the motion. Udyotakâra and other writers of the Nyâya School suppose a series of *sanskâras*, each generating the one that succeeds it. (संस्कारेण उत्तरोत्तरकर्म्मसन्तानो जायते स्वजन्योत्तरसंयोगेन कर्म्मणि नष्टे संस्कारेण कर्म्मान्तरजननात् एक एव संस्कार: कर्म्मसन्तानजनक: नतु कर्म्मसन्तानवत् संस्कार-सन्तानोऽपि अभ्युपगन्तुमुचित:— शङ्करमिश्र). It will be seen that the Nyâya view is adequate to explain acceleration which it logically implies. The force of *sanskâra* (शक्ति) diminishes by doing work कार्य्यकरणात्) against a counteracting force, and when the *sanskâra* is in this way entirely destroyed, the moving body comes to rest (संस्कारो यावत्–पतनमनुवर्त्तते । यथा यथा चास्य कार्य्यकरणात् शक्ति: क्षीयते तथा तथा कार्य्यमन्दतरतमादिभेदभिन्नमुपजायते —श्रीधर—न्याय-कन्दली—कर्म्मग्रन्थ)-Vega, it will be seen, corresponds to inertia in some respects, and to momentum (impressed motion) in others. This is the nearest approach to Newton's First Law of Motion in the Vaiśeṣika theory of motion.

Vega (impressed motion), or this tendency to move on in a straight line, is counteracted by contact with tangible objects (स्पर्शवद्द्रव्यसंयोग), *e.g.*, by impact or friction (including friction with the still atmosphere (स्तिमितवायु), as in the case of the arrow).

Vega (momentum) produces work in opposition to the resisting force, and thereby becomes weaker and weaker (मन्दतर मन्दतम) until it comes to an end. (तत्र वेगो मूर्तिमत्सु पञ्चसु द्रव्येषु निमित्तविशेषापेक्षात् कर्म्मणो जायते, नियत-दिक्-क्रिया-प्रबन्धहेतुः स्पर्शवद्द्रव्यसंयोग-विशेषविरोधी Prasastapâda, संस्कार निरूपणम्—मन्दस्तु वेगः स्पर्शवद्द्रव्यसंयोगमात्रेण विनश्यति यथा अतिदूरगतस्य इषोः स्तिमितवायु-प्रतिबद्धस्य-श्रीधर, संस्कारनिरूपणम्)

Causes of Pressure (नोदन) *and of Impact* (अभिघात).

Pressure is produced by contact acting in conjunction with Vega (impressed motion), elasticity, gravity, fluidity or volition; *e.g.*, the Vega of the wind produces pressure (नोदन) on the grass, that of a current of water on the reed, that of the bowstring on the arrow. Gravity with contact produces pressure, as when the earth sinks under a heavy load.

Impact is produced by contact with a body possessing Vega (impressed motion) where the contact is instantly followed by disjunction (or rebounding). If the contact continues, the result is pressure (नोदन) (तत्र नोदन गुरुत्व-द्रवत्व-वेग-प्रयत्नान् समस्त-व्यस्तान् अपेक्षमानः यः संयोग-विशेषः नोदनं अविभाग-हेतुः एकस्य कर्म्मणः कारणं तस्मात् चतुर्ष्वपि महाभूतेषु कर्म्म भवति...... वेगापेक्षो यः संयोग-विशेषः विभागहेतुः एकस्य कर्म्मणः कारणं स अभिघात तस्मादपि चतुर्षु-महाभूतेषु कर्म्म भवति — प्रशस्तपाद-भाष्य).

It is expressly noted that the four elements, earth, water, air and fire, are all subject to the forces of pressure and impact. Pressure and impact may be of different degrees (तीव्रमन्दादिभेद). So also *vega* (impressed motion, momentum.)

Illustrations of Combination of Forces.

(1) Pressure acting concurrently with impressed motion or *vega* as when the moving hand possessing Vega throws the quoit or a projectile. (पाणिमुक्तेषु गमनविधिः) ततः संस्कारनोदनाभ्याम् तावत् कर्माणि भवन्ति यावत् हस्ततोमर-विभाग इति—प्रशस्तपादभाष्य.)

Similarly, in the case of the bowstring impelling the arrow, or the potter's wheel impelled by the rod, the first motion is due to pressure (नोदन), and results in a *sanskâra* (persistent tendency to motion, impressed motion or momentum), but the subsequent motions are produced by the pressure acting concurrently with the *sanskâra* (impressed motion) (तस्मात् संस्कारात् नोदन-सहायात् तावत् कर्म्माणि भवन्ति यावत् इषुज्या-विभागः प्रशस्त-पाद, कर्म्मग्रन्थ—प्रथमं चक्रावयविनि दण्डसंयोगात् कर्म्म उत्पद्यते उत्तरोत्तराणि कर्म्माणि अभिघातात् कर्म्मजात् संस्कारात् च भवन्ति दण्डविगमे तु चक्रं तदवयवेषु च संस्कारादेव केवलात्। श्रीधर न्याय-कन्दली, कर्म्म ग्रन्थ)

(2) Impact (अभिघात) with impressed motion (संस्कार), as when the mortar thrown by the hand rebounds after striking the pestle (संस्कारापेक्षात् अभिघातात् मुसले उत्पतन-कर्म्म—प्रशस्तपाद भाष्य).

(3) Pressure (नोदन) acting concurrently with impact (अभिघात), as when the mud sinks when we strike against the ground with the feet. Here, if the feet be not in contact with the mud, but only with the surrounding ground, there is transmitted force (संयुक्त संयोग).

(पदादिभिर्नुद्यमानायमभिहन्यमानायाम् वा पंकाख्यायां पृथिव्यां यत् संयोगोनोदनाभिघातयोरन्यतरापेक्षो उभयापेक्षो वा स संयुक्तसंयोगः तस्मादपि पृथिव्यादिषु कर्म्म भवति । Prasastapâda).

(4) Gravity concurrently with *sanskâra* or persistent tendency, as in the case of a falling body in the second and following instants. Also the case of a stone thrown against the mud, where gravity (the weight of the stone) combines with the Vega of the stone to produce motion in the mud (Prasastapâda). (आद्यं कर्म्म गुरुत्वात् भवति तेन कर्म्मणा संस्कारः क्रियते तदनन्तरं उत्तर-कर्म्माणि गुरुत्वसंस्काराभ्यां जायते द्वयोरपि प्रत्येकं अन्यत्र सामर्थ्यावधारणात्—श्रीधर, न्याय-कन्दली, कर्म्म ग्रन्थे सत्प्रत्यय-कर्म्मनिरूपणम्). This case will be further noticed below.

Udyotakâra, the commentator on the Nyâya-Bhâsya, states that a heavier body falls to the ground with greater Vega (and velocity) than one that is lighter. Udyotakâra also holds, and Sridhara agrees with him, that the gravity (गुरुत्व) of a body (अवयवी) as a whole

composed of particles (अवयवा:) is not the same as the sum of the gravities of the particles. There is a difference in amount which is, however, so small as to be imperceptible. The concept of mass in the New Mechanics of Lorenz may lend some countenance to this curious metaphysical speculation. (Sridhara, गुणग्रन्थ, गुरुत्वनिरूपणम्).

(5) Volition acting concurrently with gravity, as in lifting the hand. This is accompanied by transmission when an object (*e.g.*, the quoit) is lifted by the hand.

Sanskâra (impressed motion, momentum) with or without pressure (नोदन) or impact (अभिघात) may be transmitted (दण्डसंयुक्तस्य अवयवस्य उत्तरोत्तरकर्म्माणि संस्कारात् नोदनाच्च अपरेषां संस्कारात् संयुक्तसंयोगाच्च Sridhara).

Composition of Gravity with Vega (*momentum*).

When a body is let go and falls to the ground, the force acting on it is gravity (गुरुत्व) which the astronomers ascribe to the attraction of the Earth. Motion is produced in the first instance by gravity alone, and this leads to a *sanskára* (impressed motion) in the same direction. But the force of gravity continues to operate, so that, in the moments following the first, the motion is due to gravity as well as *sanskára*. The resultant motion is one, but both the causes must be conceived as contributing to the resultant. The reason for supposing this combined action is that both gravity and *sanskára* (impressed motion or momentum) are seen elsewhere to produce motion separately.

In the case of the falling body, therefore, there is the composition of the two, gravity and vega, acting in the same direction (उभयसमावेश:) from the second instant onwards. It is as if two motions coalesced and resulted in one.

Here a good foundation is laid for the explanation of the accelerated motion of falling bodies, but Galileo's discovery was not anticipated, as Galileo's observations and measurements of motion were wanting (आद्यं कर्म्म गुरुत्वात् भवति तेन कर्म्मणा संस्कार: क्रियते तदनन्तरं उत्तरकर्म्माणि गुरुत्व-संस्काराभ्याम् जायन्ते द्वयोरपि प्रत्येकं अन्यत्र सामर्थ्यावधारणात्— श्रीधर, कर्म्मग्रंथ — तत् आद्यं गुरुत्वात् द्वितीयादीनि तु गुरुत्व-संस्काराभ्याम्, प्रशस्तपाद, कर्म्मग्रन्थ ।)

But in the case of the flying arrow or other projectile, the impulsive force which produces *vega* counteracts the force of gravity; in the end, this *vega* is lost through friction with air, and then gravity (गुरुत्व) brings the arrow to the ground. The meaning of this "counteraction" is not clear. Is it intended that the action of gravity is suspended as long as the *vega* continues? We have seen that, in the case of a body let fall, Praśastapâda expressly states that gravity (गुरुत्व) and *sanskára* (*vega*, momentum) both act in the second and following instants. Praśastapâda seems to have thought that some *sanskáras* (*e.g.*, the *vega* of an arrow or other projectile) suspend the action of gravity (गुरुत्वं संयोग-प्रयत्न संस्कारविरोधि, Praśastapâda, गुणग्रन्थ । वेगेन प्रतिबन्धात् अपतनं बहिक्षिप्तस्य शरशलाकादे: निवृत्ते नोदने कर्म्माणि उत्तरोत्तराणि इषु-संस्कारादेवापतनादिति Praśastapâda, Sridhara, कर्म्मग्रन्थ). Other *sanskáras* (*e.g.*, in the case of a falling body) coalesce with gravity to produce a single resultant motion. The later commentators (from Sridhara downwards) certainly interpret the Vaiśeṣika Sutras in this sense.

Motion of a particle in the case of a composition of forces.

Any number of motions or *vegas* may be impressed on a particle, but so long as these are in a uniform direction (नियतदिग्विशिष्ट) the resultant motion or *vega* is in a straight line and may be conceived as one. (द्वितीय कल्पना-ऽप्यैयर्थम् Praśastapâda, कर्म्मग्रन्थ). It is only when we come to Gamana (curvilinear motion) and its causes that the question of composition assumes a real significance. In all such cases, each separate particle has only one Vega (impressed motion) in a definite direction (नियतदिगाभिमुख्य) at any given instant, but the

composition of the successive motions and Vegas in the same particle produces the curvilinear motion (गमन) *e.g.*, the rotation of each constituent particle of the potter's wheel. The motion of the body (अवयवी *e.g.*, the wheel) results from the combined motions of the particles (अवयवा:). If pressure or impact produces motion in an opposite direction to the Vega already impressed on the body, the original direction would be changed, as is seen in the case of rebounding (उत्पतन) after impact (अभिघात). The mortar rebounding after striking the pestle is a typical instance of such change of direction in Vega or motion. The impressed force, *e.g.*, impact (अभिघात), produces a changed motion in a different direction. One view is that the original Vega (momentum) is destroyed before a new motion and a new Vega are produced by the impact. Others hold that the impact does not destroy the original Vega (momentum), but conjointly with it produces the changed motion and, through such motion, a changed Vega in a new direction. (उलूखलमुसलयोरभिघाताख्य: संयोगोमुसलगतवेगमपेक्षमाण: मुसले उत्पत्तेन कर्मकरोति यद्यपि प्राक्तनसंस्कारो विनष्ट: तथापि मुसलोलूखलयो: संयोग:पटुकर्म्मोत्पादक: तस्य संस्कारारम्भ साचिव्यसमर्थो भवति अथवा प्राक्तन एव पटु संस्कार: अभिघातात् अविनश्यन् अवस्थित इति *et seqq.* Praśastapāda, कर्म्मग्रन्थ).

Typical cases of curvilinear motion (Gamana).

Vortical Motion :—This is due to the contact of two bodies moving in opposite directions with a like or equal Vega, *e.g.*, two currents of air or water meeting from opposite directions. The change of direction is seen in the fact that water which flows downwards, or air which moves obliquely, may receive an upward motion as the result of such collision. अथ किमिदं संमूर्च्छनं नाम। समानजवयो: (तुल्ययोगयो:) वाय्वोर्विरुद्ध-दिक्क्रिययो: सन्निपात: Praśastapāda, वायुनिरूपणं). The Scholiast Udayana adds: वाय्वोरितिप्रकृतत्वेन स्पर्शवतोरिति तु विवक्षितम्। अपां यथा द्रव्यान्तरसंमूर्च्छनात् ऊर्द्ध्वगमनं परस्पराभिहतनदीपय:—उदायन द्रव्यकिरणावली. Sridhara notes:—तिर्य्यग्गति स्वभाव-द्रव्योर्द्ध्वगतित्वात् परस्पराभिहत बलतरङ्गोर्द्ध्वे गमनवत् असमानवेगयो संमूर्च्छनं न भवति एकेन अपरस्य विजयात्—Sridhara).

Vibratory motion (कम्पन, स्यन्दन)

This will be analysed in the chapter on Acoustics.

Rotatory motion (भ्रमण).

Each particle of the rotating body, *e.g.*, the potter's wheel (चक्र), has, at any given instant, a motion in a definite direction. The rotatory motion of the body results from the separate motions of the particles, and their persistent tendencies (संस्कारा:), joined with the fact of the rigid conjunction of the particles. When the rod strikes one part of the wheel, the motion in the part struck is in the first instant produced by impact (अभिघात,); while the other parts move through the transmission of force due to the rigid cohesion of parts. The subsequent motions in the part struck are due to continued pressure (नोदन) and the persistent tendency (संस्कार) set up by the first motion; while the subsequent motions in the other parts are explained by their own persistent tendencies and the transmission due to rigid cohesion. When the rod is disjoined from the wheel, the rotatory motion continues, being due merely to the persistent tendencies in the constituent parts and the resultant persistent tendency in the whole.

Other varieties of curvilinear motion in bodies are to be similarly explained (*i e.*, by the composition of Vegas) (तथा चक्रादिषु अवयवानाम् पार्श्वत: प्रतिनियतदिग्देशसंयोगविभागोत्पत्तौ यदवयविन: संस्कारादनियतदिग्देशसंयोगविभागनिमित्तं कर्म्म तद्भ्रमणमिति। एवमादयो गमनविशेषा:—Praśastapāda—कर्म्मग्रन्थ। एवं वेगात् दण्डसंयोगचक्रावयवे आद्यं कर्म्म दण्डसंयोगात्। अवयवान्तरेषु च संयुक्तसंयोगात् दण्डसंयुक्तस्य अवयवस्य उत्तरोत्तरकर्म्माणि संस्कारात् नोदनात् च। अपरेषां संस्कारात् संयुक्तसंयोगात् च दण्डविगमेतु चक्रे तदवयवेषु च संस्कारादेव केवलात् एवमादयो गमनविशेषा:—Sridhara).

SECTION 4.

MOTION OF FLUIDS.

Current motion (स्यन्दन, downward flow in a stream), upward motion (आरोहण, *e.g.*, evaporation, boiling, etc.), and capillary motion (अभिसर्पण, as in plants and porous vessels) are three varieties of fluid motion which require explanation. To this may be added vortical motion (संमूर्च्छन), and (स्यन्दन) wave motion which will be noticed in the chapter on Acoustics.

1. Current Motion स्यन्दन

This is conditioned by fluidity in particles, but Sankara Misra notes that in the downward flow of water, gravity in the fluid particles is the efficient cause (गुरुत्वात् निमित्त-कारणात् असमवायि-कारणेषु—Sankara Misra, उपस्कार). When the water is enclosed on all sides, as in a vessel, the downward flow (स्यन्दन) is counteracted. Here the fluidity does not produce motion, because, in the case of the particles in contact with the enclosing body, there is the resistance (प्रतिबन्ध) of the latter, which is transmitted to the other particles, and this counteracts the fluidity (स्रोतो भूतानामपां स्थलान्निम्नाभिसर्पणं यत् तत् द्रवत्वात् स्यन्दनं कथं समन्तात् रोध: संयोगेन अवयविद्रवत्वम् प्रतिबद्धं उत्तरोत्तरावयव-द्रवत्वानि संयुक्तसंयोगै: प्रतिबद्धानि—Praśastapâda, कर्म्म ग्रन्थ).

2. Upward Motion (आरोहण, *e.g.*, evaporation).

In evaporation, the fluid particles are rarefied, and remain in a fine state of suspension; the rarefaction is due to the impulse (नोदन) or impact (अभिघात) of the heat particles in the sun's rays, and the upward movement is due to their contact with the air under this impulse or impact. Sankara Misra notes that in boiling there is a similar upward movement of water particles under the impact of heat rays. (नाड्यो वायुसंयोगात् आरोहणं नोदनापीडनात् संयुक्तसंयोगात् च। Sutras 5 and 6, Ahnika 2, Chap 5, Vaiśeşika Aphorism). (यथा स्थालीस्था आप: क्वथ्यमाना: वायुमुखवह्नि-रश्मय ऊर्द्ध्वम् नयन्ति—Sankara Misra, उपस्कार).

N.B.—These two Sutras of Kanâda have been interpreted by the late Gangâdhara Kaviratna in his commentary to refer to the upward conduction of water in pipes by the pressure of air.

The mention of the transmitted pressure (संयुक्तसंयोग) of the air seems to lend some countenance to Gangâdhara's view, and the word Nâḍi (नाड्य) offers no difficutly, being taken in its usual sense pipe (नालिका, Nâlikâ) while the current interpretation does violence to the common acceptation of the word.

3. Capillary Motion (अभिसर्पण)

Two instances are given,—the ascent of the sap in plants from the root to the stem, (अभित: सर्पणं मूले निषिक्तानामपां यत्ने —Sankara Misra) and the penetrative diffusion of liquids in porous vessels, *e.g.*, of the oil or ghee in an earthen jar (कुम्भादौ अन्तर्निहितानां तैलघृतादीनां स्यन्दन अपनञ्च). Heat particles have a like penetrative power (दृष्टश्चाभिरोधे भर्ज्जनकपालादौ तेजस: पच्यमानद्रव्य पाकसिद्धये: कलशे च निषिक्तानां अपां शीतस्पर्शग्रहणादनिरोध:—Jayanta, न्यायमञ्जरी, Ahnika 8, इन्द्रियाणां प्राप्यकारित्वम्)

This is ascribed to *adrişta*, as the cause cannot be ascertained by either perception or inference (including hypothesis) (प्रत्यक्षानुमानाभ्यां अनुपलभ्यमानकारणम् —Sridhara.)

SECTION 5.

INTERESTING EXAMPLES OF MOTION ASCRIBED TO ADRIŞTA (UNKNOWN CAUSE, UNEXPLAINED NATURE, FINAL CAUSE.)

The first motions in primordial atoms at the beginning of Creation are attributed to *Adrişta*. Among movements in masses of matter so caused are noted the motion of the globe of the earth and similar other bodies (महाभूतानां भूगोलकादीनां प्रभवोनं चलनम् Praśastapâda

with Sridhara's commentary, कर्म्मप्रन्थ). Most probably this means earthquakes, tides, etc. Âryabhata and his school would no doubt bring under this head the diurnal motion of the earth. It is interesting to note in this connection that Bhâskara refutes the Buddhist hyphothesis of the earth falling perpetually *in vacuo*, by arguing that the earth must remain balanced in space, as there is nothing outside to attract it.

The movement of the needle (iron in general, as Sankara Misra notes) towards the magnet is another example of unexplained motion in matter. Cleaning and right placing of the magnet (संमार्ज्जनम्, ऋजुस्थापनम्) are necessary सूचीनां लौहशलाकानां, अयस्कांताभिमुखगमनम्, सूच्यादयुपलक्षणम् अयस्कान्ताकृष्टलौहमात्रमभिप्रेतम्—Sankara Misra.

Similarly amber attracts grass (straw, etc.)

(तृणकान्तमण्याकृष्टानां तृणानां गमने Sankara Misra, on Sutra 15, Ahnika 1, Chap V.)

Involuntary movements of the hand under the influence of the hypnotist's *mantras* (incantations) are also attributed to *adriṣta*.

SECTION 6.

MEASUREMENT OF MOTION. UNITS OF SPACE AND TIME.

The solar day was taken as a natural measure or division of time. In the Nyâya-Vaiśeṣika School, the day of 24 hours (solar) is stated to contain $30\times30\times30\times18\times2\times2$ units of time (kṣaṇas). The Nyâya unit of time therefore measures 2/45ths of a second. The smallest measure of time mentioned by the astronomers is the Truti which is =1/33750th of a second.

The natural measure of length was the cubit (Hasta), of which there were two fixed standards (the greater and the lesser cubit). The smallest measure of length mentioned in the Silpa-sâstra (Technology) is the Paramâṇu, which is about 1/349525th of an inch. This is the same as the Trasareṇu of the Nyâya-Vaiśeṣika School, which stands for the thickness of the minimum visible (the finest mote perceptible in the sunbeam, as it comes slanting into a dark room through a chink).

Average velocity (स्थूलगति —Bhâskara) was measured in accordance with the formula

$$v=\frac{s}{t}$$

but no unit of velocity appears to have been fixed upon. There was no idea of acceleration, and of course no measurement of force. Where the velocity is uniform, the interval of time may be of any amount (स्थूलकाल), but where the velocity is variable, (प्रतिक्षणसमागतिः—Bhâskara), an indefinitely small quantity of time (सूक्ष्मकाल) must be taken; in other words, the positions of the particle in two successive *instants* must be considered, and the velocity must be supposed to be uniform during this interval (conceived as indefinitely small, सूक्ष्म) It was in this way that Bhâskara determined the instantaneous motion of a planet (तत्कालिकी गति)

Component of velocity.

The astronomers measured the motion of a heavenly body in different directions (longitude, right ascension, etc.), and calculated separately the components of motion (गतिकल्पाः) in these directions.

And they adopted the device of transferring such component velocities from one body to another in the computation of relative motion (*e.g.*, एवं सति आचार्येण लाघवार्थं स्फुटघटीसम्बन्धिन्यो गतिकला अर्के प्रक्षिप्ताः Bhâskara, Siddhânta-Siromaṇi, Gaṇitâdhyâya, Ghatisphuti-prakaraṇa).

SECTION 7.

NOTION OF THREE AXES.

Motion, we have seen, was defined as the change of position of a particle in space. To conceive position in space, Vâchaspati takes three axes, and the position in space of one particle relatively to another may be indicated by distances measured along these three axes (*vide* my paper on The Mechanical, Physical and Chemical Theories of the Hindus, in Dr. P. C. Ray's Hindu Chemistry, Vol. II, pp. 211-212). This remarkable analysis (circa 842 A.D.) वस्यङ्कुवसुवत्सर Vâchaspati, Nyâyasuchinibandha) anticipates in a rudimentary manner the foundations of solid (co-ordinate) geometry, eight centuries before Descartes.

The principle of the differential calculus applied to the computation of motion (variable motion.)

Bhâskara (1150 A.D.) in computing what he calls the "instantaneous" motion (तात्कालिकी गति) of a planet compares its successive positions in two successive instants, and regards the motion as constant during the interval which he conceives to be indefinitely small (सूक्ष्मकाल). This is equivalent to the determination of the differential of the planet's longitude, and the process bears "a strong analogy" (to quote the words of Mr. Spottiswoode, the Astronomer Royal) "to the corresponding process in modern mathematical astronomy." I have elsewhere shown that Bhâskara's process was not merely analogous to, but virtually identical with, that of the Differential Calculus, Mr. Spottiswoode's cautious reservation having been due to his want of acquaintance with the original and the insufficiency of the materials placed before him. (*Vide* my paper on the Mechanical, Physical and Chemical Theories of the Hindus in Dr. P. C. Ray's Hindu Chemistry, Vol. II, pp. 158-163.)

SECTION 8.

RELATIVE MOTION.

The phenomenon is noticed among the hallucinations of sense) (नाव्यारूढस्य गच्छतः पर्वतादीनि विजानन्ति भ्रमेण भ्रमतश्च तान् -Kumârila, Sloka Vârtika, p. 520). Astronomers like Âryabhata and Lalla, who believed in the diurnal revolution of the Earth from the West to the East, explained the apparent revolution of the starry Heavens in the opposite direction by the principle of relative motion.

SECTION 9.

SERIAL MOTION.

Several Santânas (series) of motions are incidentally noticed, *e.g.*, vibration (स्पन्दन, कम्पसन्तान), wave-motion (वीचितरङ्ग, current motion (स्यन्दन).

In an interesting passage, Charaka notes three instances of serial motion, *viz.*, those of water, sound and light (जलसन्तान, शब्दसन्तान and अर्चिःसन्तान) to which he compares the course (सन्तान) of chyle (or chyle blood) in the Dhamanis (veins) and other ducts of the body.

Dalvana thinks that downward, oblique and upward currents of chyle are respectively intended by the three illustrations; but Chakrapâni points out that the Santâna (wave) of sound travels in all directions (the same is of course true also of light); and that differences in speed (and not in direction) are here meant. In other words, a Santâna of sound travels more rapidly than that of water and less rapidly than one of light (अर्चिःसन्तान), and Charaka's meaning is that the metabolic course may complete its circuit with greater or less speed. Whether, in this passage, the three Santânas are viewed as waves or currents is not specified. But the difference between a wave (वीचि) and a current (स्यन्दन) was well-known.

A current of water (स्यन्दन, downward flow) consists of particles moving in an uninterrupted series under the action of gravity and fluidity (गुरुत्व and द्रवत्व, Sankara Misra). A wave (वीचितरङ्ग), on the other hand, is constituted by the transmission of vibratory motion (स्पन्दन) in the water particles (*e.g.*, Jayanta, पतद्घनपयोबिन्दुसन्देाहस्पन्दनक्रमात् Nyâya-Manjari, Ahnika II).

A ray of light, on the other hand, was supposed to imply the rectilinear propagation of indefinitely minute corpuscles in all directions, with inconceivable velocity, and a sort of conical dispersion (अचिन्त्योहि वेगातिशयः तेजः प्रसर्पति पृथग्रत्वात्-Udyotakâra, Vâchaspati).

CHAPTER V.

HINDU IDEAS ON ACOUSTICS.

SECTION 1.

ANALYSIS OF SOUND.

The Mimâmsakas :—In their analysis of Sound, the Mimânsakas distinguish between three elements : (1) Nâda a quality of Vâyu (air), which is the physical basis of audible sound, (2) Dhvani, sound as heard, audible sound, and (3)—in the case of significant sound,—Sphota, 'transcendental' or 'intelligible' sound, representing the Platonic ideas or *logoi*, which are eternal (नित्य), ubiquitous (व्यापक), and noumenal (निराधार, lit., without substrate or ground—Kumârila). The Sphotas are manifested by the Dhvanis (audible sounds), of course only in the case of words (शब्द, संज्ञा). Upavarṣa, the teacher of Panini, rejects the *sphotas* in favour of the *varnas*, which are conceived to be "phonetic moulds" with natural significance.

As regards sound in its physical aspect and the mode of its propagation, some of the Mimânsakas content themselves with saying that Vâyu (air) has a special quality (Nâda), which causes audible sound, (नादो वायुगुणः वायुर्वा यदि कल्प्येत — Kumârila, Sloka-Vârtika). (वायुरेव तात्वादिस्थानसंयोगात् शब्दगुणको निष्पद्यते, शब्दस्यापि वायुगुणत्वं वेदितव्यम्—Pârtha-Sârathi Misra, Nyâyaratnâkara). Others, including the teachers of the Sikshâ (Vedic chanting), hold that the physical basis of sound is a series of air movements (वायुसन्तान, cf. Udyotakâra's and Vâchaspati's reports) ; in other words, the air particles themselves flow in a current in all directions, being obstructed in their path by the impact of tangible objects (*i.e.*, material bodies), and the movement ceases, as in the arrow, when the moving force is thus exhausted (*e.g.*, स गच्छनसर्वतोदिक्षु उद्दामवेगाहितक्रियः शरवत् वेगशान्त्यैव न दूरं गन्तुमर्हति...शिक्षाविदस्तु पवनात्मकमेव शब्दमाचक्षते, Jayanta Nyâya-Manjari). But the orthodox Mimânsâ view is that of the Mimânsâ Doctor, Savara Svâmi, who holds that Nâda (the physical basis of sound) is a wave motion of air, being the transmission of conjunctions and disjunctions in the minute particles of air, the wave originating in the first impact, and being continued by the successive impacts of the minute particles (*e.g.* संयोगविभागानैरन्तर्येण क्रियमाणाः शब्दमभिव्यञ्जन्तो नादशब्दवाच्याः (17-1-1) अभिघातेन हि प्रेरिता वायवः स्तिमितानि वाय्वन्तराणि प्रतिबाधमानः सर्वतो दिक्कान् संयोगविभागान् उत्पादयन्ति यावद्वेगं अभिप्रतिष्ठन्ते । ते च वायोरप्रत्यक्षत्वात् संयोगविभागा नेापलभ्यन्ते । अनुपरतेषु एव तेषु शब्द उपलभ्यते । नेापरतेषु अतएव च अनुवातं दूरात् उपलभ्यते शब्दः—Savara Bhâshya, Sutra 13, Pada I, Adhyâya I). In this view, the particles of air (वाय्ववयवाः) are subject to a vibratory motion (a sort of *parispanda*) in the production of sound (परिस्पन्द विलक्षण—Jayanta, Nyâya-Manjari). The Vâkyapadiya describes articulate sounds (*varnas*) and indeed all sounds (*sabdas*) as only forms of air set in motion, with rarefaction and

condensation (प्रचय), and capable of variations of velocity and configuration (लब्धक्रिय: प्रयत्नेन वक्तुरिच्छानुवर्त्तिना स्थाने स्वभिहतो वायु: शब्दत्वं प्रतिपद्यते । तस्य कारणसामर्थ्यात् वेगप्रचयधर्म्मिण: संनिपातात् विभज्यन्ते सारवत्योऽपि मूर्त्तय: । Vâkya-padiya, Kânda 1, Sloka 109).

Nyâya-Vaiśeṣika :—The early Nyâya writers hold that the sound-wave (शब्दसन्तान) has its substrate in Akâsa (ether) and not Vâyu (air). Later writers (*e.g.*, Vâchaspati in the Tattvavindu) add that sound itself as a phenomenon is not to be conceived as a mode of motion (*parispanda*), for Akâsa, the substrate, is, in the Nyâya view, incapable of motion. (न तावत् परिस्पन्दस्तस्य मूर्त्यनुविधायिनो द्रव्ये विभुनि विभुगुणे वा शब्दे मूर्त्यभावेना संभवात् — Tattvavindu). At the same time, the propagation of sound must be conceived on the analogy of waves in water (वीचितरङ्गन्याय). Udyotakâra in the Vârtika, Váchaspati in the Tâtparyyatîkâ, and Jayanta in the Nyâya-Manjarî controvert the three views current in the Mimânsâ school,—(1) that Nâda, the physical basis of audible sound, is a specific quality of Vâyu (air), (2) that sound in its physical aspect, is constituted by a series of air movements of the nature of a current (वायुसन्तान), and (3) that it is not air currents but air waves, series of conjunctions and disjunctions of the air particles or molecules (वाय्ववयवा:, वायुपरमाणव:), that constitute the Nâda, the sound physical, to which, in the case of significant sounds, the Mimânsakas assign the function of manifesting the *sphota*, 'transcendental' or 'intelligible' sound (logos, the word)—(*Vide* Udyotakâra Vârtika, Adhyâya 2, Ahnika 2, Sutra 14). Also Tâtparyyatîka, माभूत् वायुसन्तानो मा च भूततद्गुणो नाद: शब्दस्य व्यञ्जक: वायवीयास्तु संयोगविभागव्यञ्जका भवन्ति इत्यतआह etc., loc. cit. Against these views, the early Nyâya Doctors maintain that sound is a specific quality of Akâsa (ether) and not of Vâyu (air). At the same time, they admit that the impact which originates the sound phenomenon (अव्याप्यवृत्ति अयावद्द्रव्यभावि विशेषगुण) in Akâsa does so by setting up a vibration in the molecules of the object struck (*e.g.*, a bell), and that these vibrating molecules impinge against the air molecules in contact (वायुपरमाणव:, आध्यात्मिकवायु:). In other words, though Akâsa is the substrate (आश्रय), the efficient cause of sound (निमित्तकारण) is to be found in the mechanical impact (अभिघात) of vibrating molecules of sonorous bodies against contiguous molecules of air. As to the propagation of sound, the early Nyâya-Vaiśeṣika writers content themselves with stating that the first sound thus produced in the substrate Akâsa by the impact of the vibrating molecules (*e.g.*, of a bell) against the contiguous molecules of air, produces a second sound in the contiguous Akâsa, and the second sound, a third, and so on, in the same way as waves are generated in water, until the last sound sets up a vibration in the ear-drum (कर्णशष्कुलि). Of course, this propagation of sound-wave in Akâsa (ether) is effected by means of the air-wave as its vehicle. This is the Nyâya-Vaiseṣika hypothesis (कल्पना) of an independent sound-wave (शब्द-सन्तान). Akâsa (ether) is motionless, but the air-wave would not be transmitted, if the air molecules were not inter-connected by Akâsa. Prasastapâda, the Vaiseṣika Doctor, for example, describes the first sound as giving off a second, the second a third, and so on, expanding in Akâsa, in the same way as waves are supposed to propagate themselves in the ocean शब्दोऽम्बरगुण: संयोगविभागशब्दज:............................ स्थानवायुसंयोगापेक्षमानात् स्थानाकाशसंयोगात् वर्णोत्पत्ति: । अवर्णलक्षणोऽपि भेरीदण्डसंयोगापेक्षा । भेर्य्याकाशसंयोगात् उत्पद्यते । वेणुपर्वविभागात् वेण्वाकाशविभागाच्च शब्दाच्च शब्दाच्च संयोगविभागनिष्पन्नात् वीचिसन्तानवत् शब्दसन्तान इत्येवं सन्तानेन श्रोत्रप्रदेशमागतस्य ग्रहणम् । Prasastapâda. यथा जलवीच्या तद्व्यवहिते देशे वीच्यन्तरमुपजायते ततोऽप्यन्यत् ततोऽप्यन्यदित्यनेन क्रमेण वीचिसन्तानो भवति तथा क्रमेण शब्दसन्तानो भवति । नन्वेषा कल्पना कुत: सिद्धयतीत्याह etc., Sridhara, *ibid*). On this hypothesis, the locus of the sound at any moment forms a circle in Akâsa, and the propagation is carried on, in the air, by means of ever-expanding circles, as in the case of waves in water. But this analogy is rejected by some (*e.g.*, Udyotkâra), who hold that the first sound gives off, not one sound in a circle, but an indefinite number of sounds in all

directions, and each of these again gives off another, and so on, so that sound may be said to expand by successive concentric spherical layers, even as the Kadambakoraka (the so-called bud of the *nauclea kadamba*) expands by successive concentric spherical layers of filaments which shoot forth from one another. On the first of these two hypotheses, the air-wave implied in the transmission of sound is of the nature of what we call transverse waves; - on the second, of the nature apparently of longitudinal waves. In any case, it is clear that the orthodox Mimânsa view of Śavara Svâmi that the air-wave constituting physical sound means a series of mere conjunctions and disjunctions of air particles with rarefaction and condensation, सर्वतोदिक्कान्–संयोगविभागानैरन्तर्य्येण, (Śavara, प्रचय, Vâkyapadiya) implies longitudinal waves वीचितरङ्गन्यायेन तदुत्पत्तिरतु कीर्त्तिता कदम्बकोरक न्यायादुत्पत्तिः कस्यचिन्मते Visvanâtha, Bhâshâ Parichheda, Sloka 165. परिशेषात्तु सन्तानसिद्धिः। तत्राद्यः शब्दः संयोग-विभाग-हेतुकः। तस्मात् शब्दान्तराणि कदम्बगोलकन्यायेन सर्वदिक्कानि । तेभ्यः प्रत्येकमेकैकः शब्दः मन्दतरतमादिभावेनाश्रयाप्रतिबन्धमनुविधीयमानः प्रादुरस्ति । ततोऽन्त्यस्यातिमान्द्यात् शब्दान्तरोत्पत्ति-शक्तिविघातो येन केनचित् प्रतिबन्धात् भवति (Udyotakâra, II, 2, 14). As the momentum of the impact series (which constitutes the efficient cause of the sound-wave) grows feebler and feebler in the course of transmission through the air particles, the sound at last dies away. Gangeśa in the Chintâmani holds that the propagation is not from molecule to molecule, but travels in ever-expanding circles as in water-waves, perhaps in spherical layers by compression of masses of air; and these air-waves, the vehicles of sound, are exceedingly swift. This explains the velocity of sound. (शब्देन च अव्यवहितपरमाणुदेशोत्पादक्रमेण न शब्दारम्भो येन मेघजादिशब्दानां भूलोक प्राप्तियुंगान्तरेऽपि न स्यात् । किन्तु मेघाद्यभिहतं सर्वतोगामि-महावायोर्मइति देशे संयोग-निमित्तमासाद्य आद्यशब्देन सर्वे दिग्वन्तशब्दः एक एव जन्यते उत्तरोत्तरेणापि अधिकाधिकदेशगत: सर्वत्र एकैक एव शब्दः वीचितरङ्गवदुपपद्यते वायोश्च नयनवत् महावेगतया शीघ्रगामित्वेन अग्रिमशब्दारम्भात् आद्यशब्दानन्तरं अचिरेणैव शब्दोपलम्भः । वायोरेव च मन्दतरतमादिक्रमेण मन्दादिशब्दोत्पत्तिः यथा आद्य शब्देन कदम्बगोलकवद् दशदिशि दशशब्दा आरभ्यन्ते तैश्च दशशब्द सन्ताना इति (Gangeśa, Tattva Chintâmani).

But how does the first sound produce the second, the second the third, and so on? At every step, the efficient cause, the impact of some vibrating molecule against a contiguous molecule of air, must be posited, and this is equally applicable to a sound produced by a sound, (शब्दजशब्द) as to one produced by conjunction and disconjunction (संयोगज or विभागज). In other words, the sound-wave (शब्दसन्तान) in Akâsa necessarily implies an air-wave The Mimânsaka view, then, that explains the propagation of sound by the transmission of the original oscillatory motion through the successive layers of air by means of successive impacts or pressures producing conjunction and disjunction of air molecules (वायवीयाः संयोगविभागाः—Śavarabhâshya), or rarefaction and condensation (प्रचय—Vâkyapadiya), is also implied in the Nyâya-Vaiseshika doctrine of the sound-wave (शब्दसन्तान), the difference being that in the latter the air-wave, which is conceived as a mode of serial motion (गति-सन्तान) is only the vehicle or medium of propagation of a so-called sound-wave in Akâsa which is not itself a mode of motion. This is what we find expressly and elaborately formulated in the later Nyâya-vaiśeșika (*vide* Gangeśa, Chintâmani, supra).

SECTION 2.

ANALYSIS OF VIBRATORY MOTION, E.G., OF A BELL (IN AIR).

The molecules of a bell vibrate when the bell is struck. The question is—what is the nature of this vibratory movement? Vâtsyâyana and Udyotakâra answer that when the hand strikes the bell, some of the molecules are displaced (from their stable position,—*i.e.*, there is *karma* in the molecules), and thus a Sanskâra (here a kinetic Sanskâra, momentum) is generated (संस्कार, कम्पसन्तानसंस्कार, Vâtsyâyana and Vâchaspati), and the molecules swing forward under the action of this Sanskâra, until

they strike the contiguous molecules of air. This now is a case of mutual impact which divides the momentum between the colliding masses, and the bell-molecules begin to swing backward, the motion continuing under the action of the diminished Sanskâra, until they come in collision, again, with other air-molecules; and then the process is repeated, and the bell-molecules begin to swing forward and backward, until the original energy which is parted with in some measure at each impact becomes so feeble as to be unable to produce any kinetic disturbance (कर्म्म). Similarly, the air-molecules themselves are set vibrating by means of these impacts, and the transmission of the motion would form the wave of air, which the later Nyâya-Vaiśeṣika expressly posit as the vehicle of the sound-wave. But Udyotakâra never conceived vibration *in vacuo*, nor does it appear if he meant to include the second species of Sanskâra (elasticity, sthitisthâpaka sanskâra) as converted from its potential state (अतीन्द्रियत) into kinetic energy, and thus contributing to the momentum (*vega*). He uses the generic term Sanskâra, which comprehends elasticity as well as momentum due to impressed force. His commentator Vâchaspati does not go into details, and does not analyse the momentum. Later writers, however, expressly state that elasticity (sthitisthâpaka sanskâra) is one of the causes of vibration, and that elasticity resides not only in the element of earth, but also in air, water and *tejas* (cf. Visvanâtha).

घण्टायामभिहन्यमानायां तारस्तारतरो मन्दो मन्दतर इति श्रुतिभेदान्नानाशब्दसन्तानोहि अविच्छेदेन श्रूयते Vâtsyâyana, II, 2, 3.6 पाणिसंश्लेषमपेक्षमाणात् कर्म्मणः पाणि-घण्टा-संश्लेषात् पाणिगतवेगापेक्षात् घण्टायां कर्म्म तत्कर्म्म पाण्यभिघात-मपेक्षमाणं विभागसम-कालं संस्कारं करोति। सा चलन्त्याध्यात्मिकं वायुमुपगृह्णाति सा च वायुनाभिता पुनः कर्म्म करोति। ततः कर्म्मणः संस्कारः संस्कारेण पुनः कर्म्म पुनर्वायूपग्रह इत्येवमादिन्यायेन संस्कार उत्पद्यते। तत्र अन्त्यस्यातिमान्द्यात्घण्टायां महाभूतक्षोभशक्तेरभावः ततो वायूपग्रहोच्छेदः ततःसंस्कारक्षय इति (i) Udyotakâra Vârtika, Adhyâya 2, Ahnika 2, Sutra 36. (घण्टातद्वयवसंयुक्ता वायुपरमाणव एव आध्यात्मिको वायुः Vâchaspati Tâtparyyatika, loc. cit. also संस्कार वेगाख्यं करोति)—But cf. Visvanâtha संस्कारभेदो वेगोऽथ स्थितिस्थापकभावने। मूर्तमात्रे तु वेगः स्यात् कर्म्मजो वेगजः क्वचित्। स्थितिस्थापकसंस्कारः क्षितौ केचिच्चतुर्ष्वपि। अतीन्द्रियोऽसौविज्ञेय क्वचित् स्पन्देऽपि कारणम् Bhâshâ-paricchcda, Slokas 157-159.

As the air-wave forms the vehicle of the sound-wave, if it does not constitute the sound-wave itself, the favourable or retarding influence of currents of wind is easily explained. The presence or absence of water (and other intervening objects) offering greater or less resistance to the transmission of the wave-motion also easily accounts for the greater or less distance to which the sound is carried.

SECTION 3.

ECHO.

प्रतिध्वनि—Echo was supposed to be a reflection of sound. Some consider it to be an after-sound, a sound generated by sound. Others suppose it to be due to the reflection of sound in the same way as an image in water or in a mirror (प्रतिबिम्ब) is due to the reflection of light. There is an element of hallucination in either case (बुद्धिपरिणामविशेषः)—the image in water is not a real image, neither is the echo the real sound it is taken to be (रूपवत्त्वं च न सामान्यतः प्रतिबिम्बप्रयोजकं शब्दस्यापि प्रतिध्वनिरूपप्रतिबिम्बदर्शनात्। न च शब्दजन्यं शब्दान्तरमेव प्रतिध्वनिरिति वाच्यं स्फटिकलौहित्यादेरपि जपासन्निकर्षजन्यतापत्त्या प्रतिबिम्ब-मिथ्यात्वसिद्धान्तक्षतेरिति। प्रतिबिम्बश्च बुद्धेरेव परिणामविशेषो बिम्बाकारो जलादिगत इति मन्तव्यम्। Vijnânabhikṣu, Pravachana-Bhâṣya, Chap. I, Sutra 87.)

SECTION 4.

PITCH, INTENSITY AND TIMBRE.

Sounds differ from one another by their pitch (तारमन्द्रादिभेद), by their intensity (तीव्रमन्दादिभेद), and by their quality or timbre (असाधारण धर्म.) When a bell is struck, an indefinite number of notes (श्रुतिभेद, tones and overtones) are emitted, of varying pitches; and the notes die away, becoming less and less intense. Now we know that the molecules swing to and fro, and that the Sanskâra (momentum, vega) of the vibrations (कम्पसन्तानसंस्कार) grows feebler and feebler. The differences in pitch (tones and overtones) as well as in intensity must be due to variations in the Sanskâras of the vibrations. The distinguishable pitches (called Srutis, श्रुतिभेद) as well as the degrees of intensity (तीव्रमन्दादि) must be ascribed to variations in the *vega* (momentum), and, by implication, the frequency, etc., of the vibrations.

Cf. Vâtsyâyana, II, 2, 36—घण्टास्थं सन्तानवृत्तिसंस्कारभूतं पटुमन्दमिति वर्त्तते तस्यानुवृत्त्या शब्दसन्तानानुवृत्तिः पटुमन्दभावाच्च तीव्रमन्दता शब्दस्य तत्कृतश्च श्रुतिभेदः *Vide* also Udyotakâra's analysis of vibration based on Vâtsyâyana— घण्टायामभिहन्यमानायां तारस्तारतरो मन्दोमन्दतर इति श्रुतिभेदान्नानाशब्दसन्तानो हि अविच्छेदेन श्रूयते। सन्तानवृत्तित्वात् मन्दतरमन्दतमादिभिन्नरूपानुविधायिनं शब्दमुत्पादयन्ति तत्र कारणं संस्कारः— Udyotakâra Vârtika, Adhyâya 2, Ahnika 2, Sutra 36 – सन्तानवृत्तिना कारणेन श्रुतिभेदोत्पत्तिः Vâchaspati, Tâtparyyatikâ, loc. cit.)

Sounds also differ from one another in volume or massiveness in the case of coalescence (समानजातीयोपचय). A sound both loud and massive is called महान् (large)—एवं शब्दसन्तान एव तारः महान् इत्युच्यते तत्राप्यस्ति समानजातीयोपचयः अस्ति च स्फुटतरत्वम् महानपि स्फुटतरः। अयमपि तथा इति महानित्युच्यते Vâchaspati, II, 2, 36.

Śavara, the Mimânsâ Doctor, explains massiveness (महत्त्व) as due to नादवृद्धि the coalescence of different air-waves, which by their simultaneous impact affect a comparatively large tract of the ear-drum (यच्चैतत् बहुभिर्भेरीमाध्मानैर्वृद्धिः शब्दमुच्चारयद्भिर्महान् शब्द उपलभ्यते। न बर्द्धते शब्दः। मृदुरेकेन बहुभिश्चोच्चार्यमाणे तान्येव अक्षराणि कर्णशष्कुलीमण्डलस्य सर्वां नेमिं व्याप्नुवद्भिः संयोगविभागनैरन्तर्य्येण अनेकशो ग्रहणात् महान् इव अवयववानिव उपलभ्यते। संयोग विभागानैरन्तर्य्येण क्रियमाणाः शब्दमभिव्यञ्जन्तो नादशब्दवाच्याः। तेन नादस्यैषा वृद्धिः न शब्दस्य—Śavara on Jaimini, Sutra 17, Adhyâya 1, Pâda 1). The Mimânsakas who resolve sounds into air waves attribute all differences, whether of pitch, intensity, or massiveness, to differences in the series of conjunctions and disjunctions of air particles that form the waves (*Vide* Vâchaspati's report शब्दानां तु संयोगविभागयोनीनां युक्तस्तद्भेदेन रूपभेदः) Cf. also the later Nyâya-Vaiśeṣika which accepts air-waves as vehicles of sound-waves :—वायोरेव मन्दतरतमादिक्रमेण मन्दादिशब्दोत्पत्तिः (Gangeśa, Tattva Chintâmani). It may be noted that the terms तीव्र and मन्द are occasionally used in a general sense, and applied to express higher and lower degrees of pitch as well as of intensity.

There are also differences of quality (शब्दस्य असाधारणधर्म्मः) The same sound *ga* (ग), of the same pitch and intensity, uttered by men, and parrots, can be distinguished —so also the sounds, even the same notes of the scale, given out by a wind instrument like the *venu*, and a stringed instrument like the *vina*. Similarly, there are sexual and even individual differences of voice (अस्ति हि शुकसारिकामनुष्यवक्त्रप्रभवेषु कारादिषु स्फुटतरः रूपभेदप्रत्ययः पुंसाम्। एवं स्त्रीपुंसप्रभवेषु स्त्रीपुंसभेदप्रभवेषु च— Vâchaspati, Tâtparyyatiká, II, 2, 14,—वीणा वाद्यते वेणुः पूर्यते वीणावेणुशब्दयोरसाधारणो धर्म्मः—Udyotakâra, II, 1, 15—वेणुवीणामृदङ्गादिप्रभवेषु भेदप्रत्ययः शुकसारिकामनुष्यकण्ठोत्थादिभेदप्रत्ययः— Gangeśa and Mathurânâtha). The sounds emitted by impact of the different Bhutas (echo from Akâsa, hissing from the wind, puffing from fire, bubbling from water, and

splitting or cracking from earth) are characteristic examples of such differences of timbre (*Vide* Panchadaśi, Bhutaviveka, Sloka 8).

The Vâkya padiya (Kânda I, Sloka 109), as we have seen, ascribes all differences (whether of pitch, volume or timbre) to the characteristic forms of the air waves, which differ from one another by their configuration (सन्निपातात् विभजयन्ते मूर्तयः), and are capable of variations of velocity (momentum, vega) as well as of rarefaction and condensation (कारणसामर्थ्यात्) प्रचयधर्म्मिण:

There are passing references to the obscuration (अभिभव) of sounds in Vâtsâyana, Udyotakâra and Vâchaspati, but the subject is treated more from a psychological than from a physical point of view (तीव्रभेरीशब्द: मन्द तन्त्री-शब्दमभिभवति न मन्द: । नानाभूतेषु शब्दसन्तानेषु सत्सु श्रोत्र-प्रत्यासत्तिभावेन कस्यचित् शब्दस्य तीव्रेण मन्दस्य अभिभवो युक्त: (Vâtsâyana, II, 2, 14, *vide* Udyotakâra and Vâchaspati, loc. cit. Here तीव्र = loud, and मन्द = low.)

SECTION 5.

MUSICAL SOUNDS.

Srutis and Svaras :—We have already seen that the distinguishable pitches are called Srutis, and they are proportioned to the vega (momentum) of the kampa-santana (vibration). Now the ratio of a note to its octave (in respect of pitch) is given as 1 : 2, —we may therefore conclude that the *vega* of the vibration in the latter case was considered to be twice as great as in the former. An indefinite number of Srutis could be interposed between a note and its octave (आनन्त्यं हि श्रुतीनां च सूचयन्ति विपश्चित: यथा ध्वनि विशेषाणामानं गगनोदरे । संगीतरत्नाकर । cf. संगीतपारिजात । केशाग्रव्यवधानेन बह्व्योऽपि श्रुतय: स्मृता:—संगीतपारिजात, Sloka 40), Twenty-two such are named and recognised for musical purposes. But a Sruti as such cannot constitute a musical tone (svara). A sruti is a simple (unmixed) and fundamental tone of a certain pitch, whereas an ordinary musical tone (svara) is really composed of a fundamental tone (sruti) and certain partial tones, (harmonics, Anurananas, (अनुरणन) The musical tones (svaras), vocal or instrumental, are therefore of the nature of what we call clangs, because, either accompanying or following the Srutis or simple fundamental tones (ह्रस्वादिमात्र) are always found certain partial tones (अनुरणन) व्यवहारे त्वसौ त्रेधा हृदि मन्द्रोऽभिधीयते । कण्ठमध्यो मूर्ध्नि तारो द्विगुणश्चोत्तरोत्तर: (संगीतरत्नाकर) हृदिमन्द्रोगलेमध्यो मूर्ध्नितार इति क्रमात् । द्विगुण: पूर्वपूर्वस्मात्—Dámodara, Sangita-Darpaṇa, Chap. I, Sloka 49. श्रुत्यनन्तरभावी य: स्निग्धोऽनुरणनात्मक: । स स्वर: उच्यते—Sangita-ratnákara —स स्वरोय: श्रुतिस्थाने स्वनन् हृदयरञ्जक: (संगीतदामोदर) द्वाविंशतिविधो मन्द्रोध्वनि: सञ्जायते हृदि । स एव द्विगुणो मध्य: कण्ठस्थाने यथाक्रमम् । स एव मस्तके तार:स्यान्मध्यात् द्विगुणक्रमात्—Sangita Samaya Sára, 1, नादाश्च श्रुतयो जातास्तत: षड्जादय: स्वरा: । प्रथम श्रवणाच्छब्द: श्रूयते ह्रस्वमात्रक: सा श्रुति: सम्परिज्ञेया स्वरावयव लक्षणा: । स्वरूपमात्रश्रवणान्नादोऽनुरणनं विना । श्रुतिरित्युच्यते Dámodara, Sangita-Darpaṇa, Chap. I, Sloka 51. The relation between a Sruti and a Svara is variously conceived as (1) परिणाम model change ; (2) व्यञ्जन manifestation ; (3) तादात्म्यम् जातिव्यक्त्योरिव the relation of genus and species ; (4) विवर्त्तन (मुखं यद्वद् दर्पणेषु विवर्त्तितं) reflection; (5) कार्य्यकारणभाव, the relation of cause and effect ; Cf. संगीत पारिजात by Ahobala, श्रुतयस्तु स्वरा भिन्ना: श्रावणत्वेन हेतुना । अहिकुण्डलवत् तत्र भेदोक्ति: शास्त्रसम्मता । संगीतपारिजात Sloka 38.

SECTION 6.

THE NOTES OF THE DIATONIC SCALE : DETERMINATION OF THEIR RELATIVE PITCH.

The pitch of a note is inversely proportional to the length of the wire (तन्त्री तन्तुस्वरो ज्ञेय: तद्दैर्घ्यव्यस्तमानत:) (सोमनाथ, quoted by Mr. Devala in his 'Hindu Musical Scale').

The pitch of the fundamental note to that of its octave is as 1 : 2 (मध्यस्थानस्थ: षड्ज: द्विगुण सम :—रागविबोध quoted by Mr. Devala).

The pitch of the fourth note (F) to that of the fundamental (C) is as 4 : 3 (उभयो: षड्जयोर्मध्ये मध्यमं स्वरमाचरेत्-संगीतपारिजात quoted by Mr. Devala).

The virbrations of the fifth note (G) to those of the fundamental (C) are as 3 : 2 (त्रिभागात्मकवीणायां पञ्चम: स्यात्तदग्रिमे । (संगीतपारिजात quoted by Mr. Devala).

Concord (सम्वादित्व) is either perfect or imperfect. The ratio of perfect concord is 3 : 2—that of imperfect concord, 4 : 3—स-प-स-म मुख्या: संवादिन: स्वरा: एकसंश्रया: प्राय: (रागविबोध quoted by Mr. Devala) *e.g.*, if D be the Vâdi, A would be a Samvâdi, if E be the Vâdi, B would be a Samvâdi, in each case a perfect concord. The pitch of D is determined from that of G, and the pitch of A from that of D, in each case by the rule of perfect concord.

Determination of the pitches of E and B :—(after Mr. Devala). This may be done in either of the following ways :-

(1) E may be determined from A, and B from E by the rule of perfect concord. This would give $303\frac{3}{4}$ as the value of the pitch of E, and $455\frac{5}{8}$ as that of the pitch of B, if the pitch of C be taken as 240 ; *or*

(2) E may be determined from C by reduction of the fifth harmonic by two octaves, a sort of imperfect concord ; and then B may be determined from E by the rule of perfect concord. This would give 300 for E, and 450 for B, if C be taken as 240.

Mr. Devala in his investigations with the "Sonochord" finds that Hindu musicians (and Sanskrit writers on music) adopted the latter values for E and B, as they tested their notes by harmonics (मेरुगतस्वयम्भूस्वरप्रकिप्रामाण्येन—रागविबोध quoted by Mr. Devala). The Hindus therefore followed just intonation.

SECTION 7.

MUSICAL INTERVALS.

Musical tones are related to one another in four ways as Vâdis, Samvâdis, Vivâdis and Anuvâdis. The mediæval compilations explain these in reference to melody, and harmony is altogether unknown, but the terms might be used to indicate relations of harmony as well. The Vâdi might in that case answer to the key-note (or tonic); and the Samvâdis to the two consonances, the fifth (2 : 3), and the fourth (3 : 4).

The rule given for the determination of a Samvâdi is 12 or 8 Srutis intervening, the intervals being therefore 13 and 9 Srutis respectively (giving the ratios $\frac{3}{2}$ and $\frac{4}{3}$).

C being the Vâdi, G and F are stated to be the Samvâdis. The first would answer to the dominant, and the second to the sub-dominant.

In the same way, it is stated that if D be the Vâdi, A would be a Samvâdi. If E be the Vâdi, B is given as a Samvâdi.

On the other hand, a two-Sruti interval (*i.e.*, a difference of a semi-tone) gives a Vivâdi, which would thus answer to a dissonance. This is given as a general rule (द्विश्रुत्यन्तरीस्वरौविवादिनौ mátanga). Other cases are also noticed ; *e.g.* E is a Vivâdi to D, and B to A, and *vice versâ* (ratio of 9 : 10).

The notes that do not come under these heads are Anuvâdis (*e.g.*, the sixth), cf. Bharata, Nâtya-Sâstra, Chap. 28, Slokas 23-24.

Also Sangita-ratnâkara :—

चतुर्विधा स्वरा वादी सम्वादी विवाद्यपि अनुवादीति । वादीतु प्रयोगे बहुलस्वरः श्रुतयो द्वादशाष्टौ वा ययोरन्तरगोचराः मिथः सम्वादिनौ तौ स्तो निगावन्यविवादिनौ । रिधयोरेव वा स्यातां तौ तयोर्वारिधापपि । शेषाणामनुवादित्वम् । (स्वराध्याय)

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